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ACTA RADIOLOGICA
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ELECTROKYMOGRAPHIC STUDIES OF NORMAL AND ABNORMAL RIGHT AURICLES

With special reference to the changes in atrial septal defect and valvular pulmonary stenosis

by

Per Ödman

The electrokymography (EKyG) of the normal auricle has been described by a number of authors, among others ENGSTRÖM et coll., ANDERSSON, and DEUTSCH et coll. These investigators have chiefly studied EKyG from the left auricle and left auricular appendage, but it is generally accepted that both auricles yield approximately similar electrokymographic patterns. BOOTH et coll., in electrokymographic studies of the right auricle, have briefly described the duration and appearance of the different segments of the curve. DACK and PALEY have discussed the contours of the right auricular EKyG. In both papers it is pointed out that considerable normal variations may occur in the pattern of the right auricular EKyG. There is, however, a dearth of information regarding both right auricular electrokymographic chronology and its local variations in shape.

With a view to throwing some light on this question, 25 patients with sound hearts from a psychiatric material have been studied electrokymographically by the present author, all on exactly similar lines. This group, the normal material, serves as a control series. The author's experience is also based on normal and abnormal EKyG from about 350 different patients, mostly with cardiac lesions.

The results from the normal material were compared with electrokymographic investigations carried out in the same way in 43 cases of congenital malformation (atrial septal defect and valvular pulmonary stenosis) in which the hemodynamic and anatomic changes were mainly concentrated in the right side of the heart.

All examinations were carried out with the patients in the sitting position. The position of the electrokymographic photomultiplier was generally adjusted to meet the topographic conditions in the particular heart chamber under examination. Thus, no definite standard positions were used, in consideration of the fact that the anatomic relations of the cardiovascular structures vary considerably.

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From Roentgen Department I (Director: Docent GUNNAR JÖNSSON) and Medical Department II (Director: Prof. GUSTAV NYLIN), Södersjukhuset, Stockholm Sweden.

Elektrokymograms were recorded over the right auricle at different levels, in the a. p. view, with the patient turned slight left, and in different degrees of right rotation. The other heart chambers as well as the great vessel trunks were also examined in every instance. Electrocardiograms (ECG) with three standard leads were used as reference curves in order to elucidate the different phases of the cardiac cycle. Throughout this paper, Lead II of the ECG is used as a reference. The apparatus used was the same as App. I described by ANDERSSON in his thesis.

The displacement of the cardiovascular silhouette recorded in EKyG is due partly to variations in volume and partly to movements in the heart or in its parts. An EKyG from a certain point on the cardiovascular silhouette thus represents several movement components. Volume variations in the structure under examination are recorded to a varying extent in the EKyG. Records from the ventricles are, under normal circumstances, relatively accurate replicas of the corresponding volume curves (BOONE et coll. and others).

Auricular EKyG, on the other hand, show considerable divergences in this respect. This is due to the fact that the auricles have thin walls with weak muscles (DEUTSCH et coll. and others) and stand in an intimately topographic relationship to other structures with large auto-movements (ANDERSSON). Not only volume variations in the right ventricle, but pendular and torsion movements etc., in the whole heart are also mirrored in right auricular EKyG.

The normal right auricular electrokymogram

Certain characteristic features, chiefly resulting from volume changes in the auricle itself, are always distinguishable in right auricular EKyG. The auricular contraction usually manifests itself as a downward deflection of the curve, 'atrial contraction descent' (Fig. 1 a and b). This is due to a decrease in volume during the contraction when blood is expelled from the atrium to the ventricle (ENGSTRÖM et coll., ANDERSSON, and others). In normal subjects, the right auricular pattern, and especially the atrial contraction descent, is most distinctly seen in curves recorded over the right auricular appendage, *i. e.* fairly high up on the right side of the cardiac silhouette, with the patient in a slightly left anterior oblique position. In the present paper, normal right auricular electrokymographic

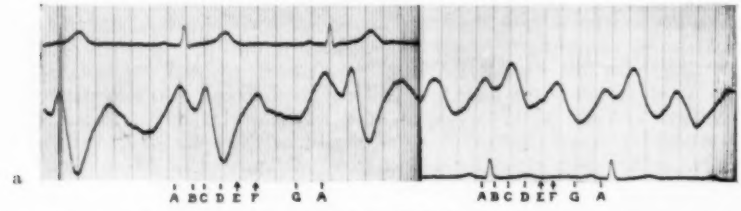


Fig. 1. Normal subjects. Right auricular EKyG. A—B: Atrial contraction descent. B—C: Isometric contraction upstroke. C—D: Rapid ejection downstroke. D—E corresponds to the reduced ejection phase and protodiastolic phase. At E (↑): Closure of pulmonary valves. At F (↑): Opening of tricuspid valves. F—G: Rapid inflow downstroke. G—A: Slow inflow upstroke. In a) the curve rises more steeply before the closure of the pulmonary valves; in b) it slopes upward more gradually before this event.

chronology generally refers to curves recorded from this area. Considerable individual and local variations in the distinctness of the atrial contraction descent are observable. In some instances, there is only a slight change in gradient at the beginning of the atrial contraction, followed by a gently descending slope or a horizontal segment (Fig. 2). Sometimes, when the curve slopes steeply downwards, towards the close of diastole, there is seen an undecided diversion in the pattern, corresponding to the onset of the atrial contraction (Fig. 3; see p. 361). This occurs only in tachycardia. These variants are sometimes recorded all over the right auricle, and at times are seen over a large part of the auricle, while the curve from the right auricular appendage shows a definite descent in connection with the atrial contraction (Fig. 4). In two normal controls, however, this event was not electrokymographically identifiable.

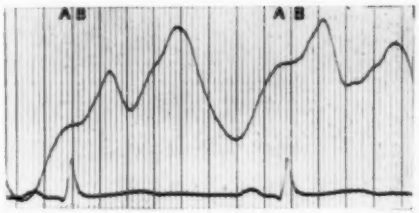


Fig. 2. Normal subject. EKyG from right auricular appendage. Curve horizontal during auricular contraction A—B.

Similar findings in the auricular electrokymographic pattern during the atrial contraction have been described by other authors, among them ANDERSSON in studies mainly dealing with left auricular and auricular appendage EKyG. According to the experience of the writer, they seldom, however, occur in one and the same individual in the EKyG of both auricles.

A short ascent in the tracing immediately prior to the atrial contraction descent has been reported both by ANDERSSON and other authors. This electrokymographic event seems to be especially marked in left auricular appendage EKyG in mitral stenosis, but it has occasionally been observed in left auricular EKyG from normal subjects. It is said (ANDERSSON) to represent "the change in shape of the auricle when it tenses before the expelling contraction begins". This phenomenon hardly ever occurs in

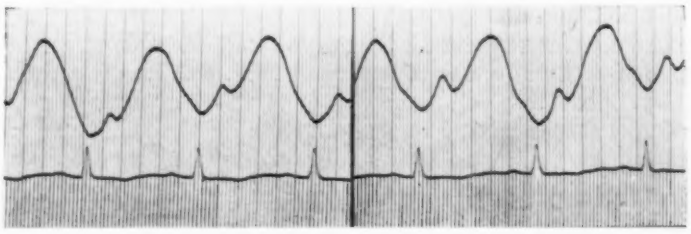


Fig. 3. Normal subject. a) EKyG from right auricular appendage. b) EKyG from middle segment of right borderline with patient in slightly left oblique position. In both curves atrial contraction descent indistinct. Relatively rapid cardiac rhythm.

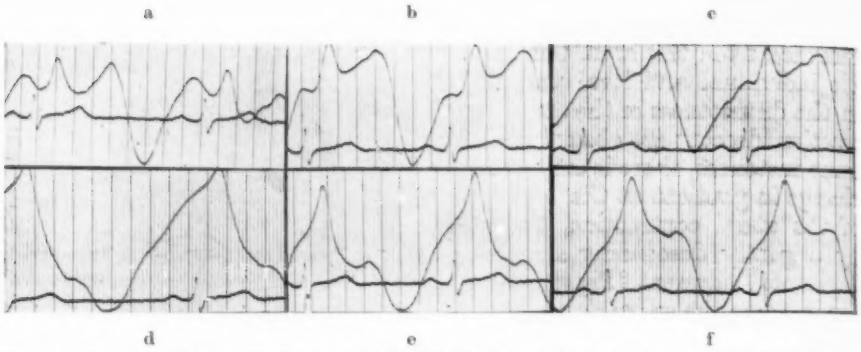


Fig. 4. Normal subject. Right auricular EKyG recorded: a) high up on right cardiac silhouette with patient in moderately left anterior oblique position (right auricular appendage), b) at same level, in slightly left anterior oblique position, c) at same level in a. p. position, d) over middle part of right cardiac silhouette in moderately left anterior oblique position, e) at same level in slightly left anterior oblique position, and f) at same level in a. p. position. Atrial contraction descent most prominent, with a distinct descending limb, in appendage tracing. In a and b, indistinct horizontal segment of curve between rapid ejection downstroke and following upward directed segment.

normal right auricular EKyG. Sometimes, however, an indefinitely delineated, rounded transition between the atrial contraction descent and the preceding segment of the curve is seen. Because of this observation, it occasionally appears as if the atrial contraction started uncommonly late in the cardiac cycle (Fig. 5). This indefinite transition is, however, never seen in tracings from the right auricular appendage. In uncertain cases, therefore, the curves from the auricular appendage should always be regarded as decisive.

The right atrial contraction descent began, in the normal material, 0.08 to 0.15 sec after the onset of the P-wave in the ECG (cf. Fig. 1). Its duration varied between 0.04 and 0.10 sec. Accordingly, 0.11 sec or more may be considered a prolongation of the right atrial contraction descent. In general, the value in the normal controls was around 0.05 to 0.07 sec. DEUTSCH et coll. and ANDERSSON (Table 1) have mentioned similar figures.

After the contraction period, the curve sometimes follows an undecided course for a few hundredths of a second (Fig. 6). This feature has been observed by BOOTH and coll., among others. These investigators maintain that "multiple forces having opposite effects on the right auricular wall are acting at this time". Following this, or in immediate association with the atrial contraction descent, the curve rises. This rise, 'the isometric contraction upstroke', is consistently found in normal right auricular EKyG (cf. Fig. 1), but displays certain local variations which will be discussed later on. It corresponds, in essentials, to the isometric contraction of the ventricles when the tricuspid valves bulge into the auricle

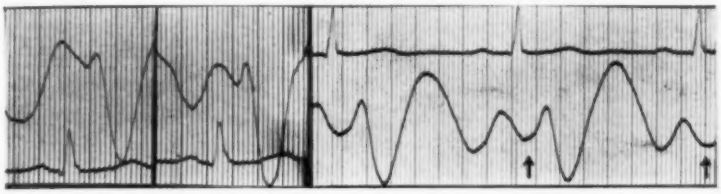


Fig. 5 a Fig. 5 b Fig. 6

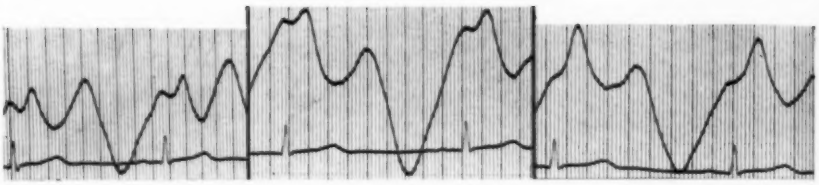
Fig. 5. Normal subjects. Right auricular appendage EKyG. a) Atrial contraction descent distinctly seen to begin simultaneously with the QRS-complex of the ECG. b) Right auricular EKyG from middle part of right cardiac silhouette. Onset of atrial contraction descent indistinct, apparently occurring after the beginning of the QRS-complex. Fig. 6) Indistinct transition between atrial contraction descent and isometric contraction upstroke (↑).

causing a rise in pressure in that chamber (ENGSTRÖM et coll., BOOTH et coll., and others). It must, however, be presumed that the contraction in the auricle has been succeeded by a certain degree of relaxation. Since the tricuspid valves are closed at this stage, the right auricle will probably begin to expand during the isometric contraction phase. Accordingly, this incident is probably also represented in the isometric contraction upstroke, as ANDERSSON has already pointed out.

The isometric contraction upstroke began 0.04 to 0.10 sec after the Q-wave of the ECG in the normal controls (cf. Fig. 1; Table 1). Its duration varied between 0.05 and 0.10 sec; as a rule the value was around 0.06 to 0.09 sec.

In right auricular EKyG, a downward deflection, 'rapid ejection downstroke', now follows (Fig. 1). This began within a narrow range 0.14 to 0.16 sec after the Q-wave of the ECG in the normal controls (Table 1). According to BOOTH et coll., this downstroke takes place 0.10 to 0.12 sec after the onset of the QRS-complex in the ECG (Table 1). Their subjects were, however, examined recumbent, and this may explain the difference. The rapid ejection downstroke is considered essentially to represent the medially directed movement of the auricular wall, when the atrioventricular septum is displaced towards the apex cordis as a result of the ventricular contraction (ENGSTRÖM et coll., BOONE et coll., and others). DACK and PALEY have pointed out that the downward deflection occurring in connection with the onset of the ventricular contraction is more pronounced in the right auricular EKyG than in the left, and this observation accords with the experience of the writer.

The rapid ejection downstroke ranged in duration from 0.03 to 0.10 sec (Fig. 1; Table 1). Both its duration and its relative amplitude are often subject to individual and local variations. This may to a large extent be attributed to alternating forces emanating from volume changes in the right ventricle, and rotatory and pendulum movements of the heart.



a b c

Fig. 7. Normal subject. Right auricular EKyG registered from right borderline with patient in slightly left anterior oblique position. a, b and c, from above downward. The isometric contraction upstroke and rapid ejection downstroke become more dominating the further toward the caudal aspect the curve was recorded. Influence from ventricular movements especially noticeable in c.

Regularly recurring local variations in the movements of the right auricular wall are often demonstrable if tracings from different segments of the wall are compared with one another. Thus, the relative amplitude, and to a certain extent also the duration, of the isometric contraction upstroke and rapid ejection downstroke increase the nearer towards the caudal aspect of the auricular wall the EKyG is recorded (Fig. 7). The ventricular elements in the auricular wall movements thus become more noticeable the closer the ventricle is approached.

Between the rapid ejection downstroke and the following, more or less upward-directed, segment of the curve there is usually a clearly distinguishable transition. The EKyG may, however, in some cases, have an unclear, almost horizontal appearance before the rise finally begins (Fig. 4 a and b). The first part of this upstroke represents the reduced ejection phase. It reflects expansion of the auricle owing to an inflow of venous blood (ANDERSSON, and others). The rise sometimes continues, however, without signs of a break during the following periods until the tricuspid valves open (BOOTH et coll.). The individual phases in late systole and early diastole can, in consequence, be only imperfectly identified. This feature has also been observed by ANDERSSON, LUISADA and FLEISCHNER, and others.

The closure of the pulmonary valves was identified in right auricular EKyG in about three-fourths of the normal material. The electrokymographically recorded movement is probably due to a temporary pressure change in the right auricle (cf. studies of normal pressure conditions in this heart chamber by BAYER et coll., and others.) The closure of the pulmonary valves is often marked by a change in gradient in the normal right auricular EKyG. The commonest change is for a steeply rising curve to take on a more flattened line after the closure (Fig. 1 a), but the opposite appearance is occasionally seen (Fig. 1 b). The closure is sometimes represented instead by an incisure. This may be preceded by a short horizontal or slightly descending curve segment (Fig. 8), reflecting the protodiastolic

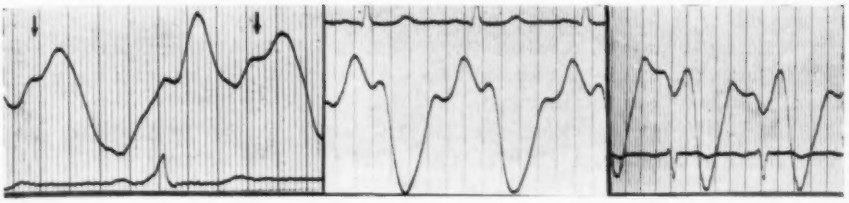


Fig. 8 Fig. 9 a Fig. 9 b

Figs. 8 and 9. Normal subjects. Right auricular EKyG. 8) A horizontal curve segment immediately before closure of pulmonary valves (↓), representing the protodiastolic phase. 9 a and b) Volume changes of right ventricle dominate movements of right auricular wall. Note patterns during rapid and slow inflow phases.

period. This type of electrokymographic pattern seems to be less common in right than in left auricular EKyG.

BOONE and associates maintain that the highest part of the curve during late systole and early diastole is usually synchronous with the closure of the semilunar valves. This would seem to be extremely rare in normal right auricular EKyG, and it has not been observed by the writer either in the normal material or in other EKyG studied.

The closure of the pulmonary valves occurred, in the normal controls, either simultaneously with the T-wave of the ECG or a few hundredths of a second afterwards (Fig. 1). The interval between this electrokymographic event and the Q-wave of the ECG was 0.25 to 0.33 sec.

Several different movement components may act on the right auricular wall during late systole and early diastole. The auricle dilates, due to the fact that blood flows in from the centrally situated veins. The increase in volume resulting from the inflow of blood continues until the tricuspid valves open (BAYER et coll., and others).

Mechanical events, emanating from the right ventricular relaxation, will also be reflected on the right auricular wall during these periods. After the ventricular contraction the atrioventricular septum moves towards the base in consequence of the relaxation of the interventricular septum and the ventricular wall. As a direct result of the pressure drop in the ventricle, the atrioventricular valves cease to bulge into the auricle. To a varying extent, depending on the heart's position in the thorax, the reversion of the atrioventricular septum in all probability brings about lateral displacement of the auricular wall during late systole and early diastole. The exact effect of the mechanical events described are, however, not quite clear. Their reciprocal time relations are uncertain. Nor is it known exactly when, and at what speed, the reversion of the atrioventricular septum takes place. Investigations into these problems by, among others, WESTERMARK, HOLMGREN, SUNDBERG, WOLFERTH and MARGOLIES have not yielded completely unanimous results.

Pendulum and torsion movements during the transitional phases between systole and diastole move the heart as a whole. In the great vessel trunks, traction and oscillations occur during the ejection periods and the closure of the semilunar valves. This is noticeable particularly in the ascending aorta, whose electrokymographic pattern sometimes diverges considerably from that of the corresponding volume curve. These movements may be transmitted to the right auricular wall with varying effect. To sum up, it may be stated that the action on the right auricular wall is highly complex during late systole and early diastole. The right auricular EKyG represents a sum total of several different types of movement components. Their reciprocal influence is subject to much individual and local variation. This may account for the irregularities in right auricular electrokymographic pattern seen during these periods.

On the opening of the tricuspid valves, the gradient of the curve changes noticeably (Fig. 1). This is due to the beginning decrease in the auricular volume. This electrokymographic incident occurred, in the normal material, 0.06 to 0.10 sec after the end of the T-wave of the ECG (Fig. 1; Table 1). Other electrokymographic investigations (cf. ANDERSSON, DEUTSCH and co-workers, and others) have revealed similar figures (Table 1).

After this event the curve usually shows a distinct drop, 'rapid inflow downstroke' (Fig. 1). This mainly corresponds to the rapid inflow phase. The greater part of the blood in the auricle flows over into the ventricle at this stage, while refilling from the central veins is relatively poor (RUSHMER et coll., WIGGERS, and others). These hemodynamic conditions produce the auricular volume decrease that is reflected in the rapid inflow downstroke (ANDERSSON, DEUTSCH et coll., and others).

The duration of this electrokymographic event was 0.10 to 0.19 sec among the normal controls (Fig. 1; Table 1). Both individual and fairly unimportant local variations were observed in the normal material in this respect.

After the rapid inflow downstroke there usually follows a more or less distinctly marked rise in the curve, 'slow inflow upstroke' (Fig. 1), corresponding to the slow inflow phase or diastasis. This ascent seems steeper and comparatively higher in right than in left auricular EKyG, and the transition between the two inflow phases usually is clearly portrayed. The duration of the slow inflow upstroke is, in the normal material, directly proportional to that of the diastoles. This finding tallies well with the results of WILLIS et coll. and of BURSTEIN, in studies concerning the duration of the different periods of the heart cycle. In the auricle, the inflow from the veins dominates over the outflow to the ventricle, during the slow inflow phase. This causes the lateral movement of the auricular wall that has been registered in EKyG (DEUTSCH et coll., ANDERSSON, and others).

The right auricular electrokymographic pattern shows, however, considerable divergences in normal subjects from what has been indicated above. This is probably

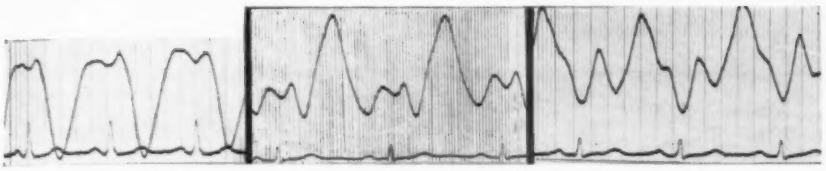


Fig. 10 Fig. 11 Fig. 12

Figs. 10, 11 and 12. Normal subjects. Right auricular EKyG. 10) Rapid and slow inflow phases not distinctly separated. Dominating influence from movements of right ventricle. Tachycardia. 11) Prominent rise during late systole and early diastole up to time when tricuspid valves open. Subsequent to this, an equally prominent drop. Slow inflow upstroke distinct. 12) A marked rise during late systole and early diastole. A steep drop during both rapid and slow inflow phases.

due to the fact that the different mechanical events are reflected on the right auricular wall to a varying extent. The most striking variants are characterized by the features now to be described.

The curve sinks with a large downward amplitude during the rapid ejection period and then rises steeply up to the moment when the tricuspid valves open. At this moment the gradient changes. The curve then runs horizontally, sinks, or rises slowly. This part represents the rapid inflow phase. Subsequently, the curve assumes another gradient (corresponding to the slow inflow phase) and the transition from the preceding phase becomes clearly distinguishable (Fig. 9). In a few unusual cases, however, this transition is difficult to detect, and the curve can then have a more or less plateau-like appearance during the ventricular filling periods (Fig. 10). This was observed in one normal control with a rapid cardiac rhythm. This phenomenon has not, on the other hand, been observed in normal left auricular or auricular appendage EKyG. These variants of normal right auricular EKyG usually are recordable all over the right auricular silhouette. In all probability, they reflect right ventricular volume changes, which thus have a dominating influence on the movements of the right auricular wall. Pressure changes in the auricle, on the other hand, manifest themselves electrokymographically as temporary changes in the dominating direction of the curve.

The opposite of these right auricular patterns, from the aspect of an influence from the right ventricle, has the following characteristic configuration.

The downward deflection during the rapid ejection phase is little evident. The curve rises chiefly during the ejection phases and the upstroke continues with a large relative amplitude until the tricuspid valves open. There then follows a distinct drop, which is interrupted by a clearly marked slow inflow upstroke (Fig. 11) or in some cases continues without a break throughout diastole and up to the start of the atrial contraction descent (Fig. 12). In the latter variant, the definite filling phases are absent or barely perceptible while at the same time the atrial contraction descent more or less fuses with the descending limb of diastole (Fig. 3). These patterns are usually recorded all over the right auricular silhouette. They seldom occur in both auricular EKyG in the same person. The variants described are characterized by laterally directed motion of the auricular wall due to venous atrial filling in late systole and early diastole, and to medial displacement during the ventricular filling periods. Pendulum and rotation movements in the entire heart may also possibly help to give these curve types their characteristic appearance. The fact that the variants are most pronounced, and occur most frequently, in medially-placed hearts gives some support to this view.

Andersson, and Soloff et coll., have described a variant in normal left auricular

Table

Different electrokymo-

Authors	Place of registration	Atrial contraction descent		Isometric contraction
		Onset	Duration	Onset
Willis et coll.	Ventricles, great vessels			
Deutsch et coll.	Auricles	0.06 to 0.14″ before 1st heart sound	0.05 to 0.08″	0.01 to 0.03″ before 1st heart sound
Andersson ...	Auricles	0.08 to 0.14″ after onset of P-wave	0.03 to 0.08″	0 to 0.06″ after R-wave
Booth et coll. .	Right auricle	0.06 to 0.12″ after onset of P-wave		
Present study .	Right auricle	0.08 to 0.15″ after onset of P-wave	0.04 to 0.10″	0.04 to 0.10″ after Q-wave

and auricular appendage EKyG in which the curve is horizontal during the ejection and subsequent short transitional phases. This pattern has not been observed in normal right auricular EKyG.

This study of normal right auricular EKyG presents no essentially new aspects concerning the auricular electrokymographic pattern; it confirms, on the whole, what other observers have already noted. An exhaustive knowledge on local variations of the normal right auricular EKyG and the timing of the different curve segments is, however, essential for those interpreting EKyG in abnormal cases.

The abnormal auricular electrokymogram

Earlier investigations

Pathologic changes in the auricular electrokymographic pattern have been demonstrated in various connections. Engström et coll. and Andersson, in particular, maintain that the left atrial contraction descent is prolonged and has a relatively increased amplitude in mitral stenosis. This event may be so drawn out that the isometric contraction upstroke is diminished. A relatively steep rise during a reduced ejection period may, according to Andersson, also be seen in left auricular EKyG in mitral stenosis. This is said (Andersson) to "depend upon filling of the auricle under high pulmonary venous pressure". A decreased descent of the rapid inflow downstroke, often combined with "a horizontal plateau during the entire diastole" also occurs in left auricular EKyG in mitral stenosis. Andersson ascribes these events to reduction in the volume decrease of the left auricle, due to "obstruction of the flow through the narrowed mitral orifice". This author also observed suspected concomitant tricuspid valve stenosis in a few cases of mitral stenosis. They had an accentuated right auricular contraction descent.

Luisada states that in cases with increased atrial pressure and auricular hypertrophy the atrial contraction descent is deep and sometimes prolonged.

Dusaillant et coll. have described cases of tricuspid valve stenosis in which the right atrial contraction descent was very large. This was thought to be due to auricular hypertrophy. The investigators in question do not, on the other hand, mention this electrokymographic change in a study of a few cases with auricular septal defect.

1

graphic incidents

upstroke	Rapid ejection downstroke		Opening of atrioventric. valves	Rapid inflow downstroke
Duration	Onset	Duration		Duration
0.03 to 0.08″		0.06 to 0.21″		0.08 to 0.30″
		0.05 to 0.08″	0.05 to 0.10″ after 2nd heart sound	0.06 to 0.09″
	0.08 to 0.12″ after R-wave		0.08 to 0.12″ after end of T-wave	0.06 to 0.09″
	0.10 to 0.12″ after onset of QRS			
0.05 to 0.10″	0.14 to 0.16″ after Q-wave	0.03 to 0.10″	0.06 to 0.10″ after end of T-wave	0.10 to 0.19″

Dack and Paley have observed congenital cardiac malformations with right heart hypertrophy in which the right auricular waves were very deep. They state this to be "suggestive of right auricular hypertrophy and dilatation". An electrokymographic pattern of this type is said to be especially marked in pulmonary stenosis and atrial septal defect. These authors have also published one right auricular EKyG from a case of pulmonary stenosis. The pattern is very similar to that observed in left auricular EKyG by Andersson, and Engström et coll., in mitral stenosis.

Grishman and associates, in a work on palpable and visible pulsations in the liver, have described two cases (Eisenmenger's complex and acute endocarditis) in which the presystolic downward movement of the right auricular EKyG was very prominent. This was considered to be due to increased amplitude and force of the right auricular contraction.

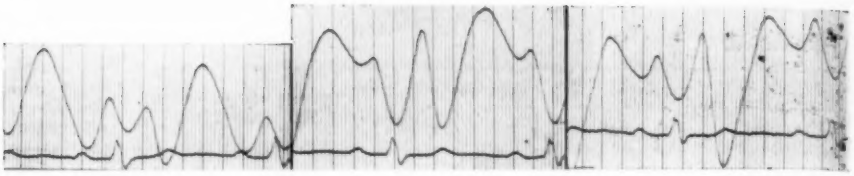
Investigations into the correlations existing between right auricular pressure conditions and electrokymographic manifestations in altered right cardiac hemodynamics have, however, not been published either by the above-mentioned authors or by any others. Long, Luisada and Fleischner, and Salans et coll., however, have noted a correlation between these events in subjects with normal right hearts.

Personal investigations

Right auricular EKyG in atrial septal defect

Thirty-two cases of atrial septal defect were examined electrokymographically. These comprise 'the atrial septal defect group'. Their ages ranged from 15 to 51 years. All the patients were examined by right heart catheterization with blood oxygen analysis and pressure measurement. Inter-auricular left to right shunt could be demonstrated in every case. The catheter passed from right to left auricle, through a defect in the septum, in all except two cases in which catheterization had to be broken off. Angiocardiography was in many instances performed in connection with the catheterization.

Variations largely resembling those occurring in ordinary right auricular EKyG were also observed in the auricular septal defect group. In addition, there were direct divergences from the normal related to altered hemodynamic and anatomic conditions.



a b c

Fig. 13. Male, aged 30. Atrial septal defect. Right auricular EKyG, a) recorded high up on right cardiac silhouette with patient in moderately left anterior oblique position, b) over middle part, and c) over lowermost part. Atrial contraction descent prominent in all tracings, particularly in b (right auricular appendage). Typical auricle curves are obtained where ventricle curves are normally found (c).

The most typical right auricular EKyG in the atrial septal defect group were recorded as a rule over the middle or even the lower part of the right borderline with the patient in a slightly to moderately left anterior oblique position. In many cases, this region was situated much lower than the site where the right auricular appendage is usually found under ordinary conditions. Right auricular records were often obtained from a relatively large section of the right heart, in other words, from parts where ventricle curves are normally found (Fig. 13). These observations were interpreted as enlargement of the right auricular appendage or of the whole of the right auricle, an assumption which in many cases was confirmed by angiocardiography.

The atrial contraction descent was often relatively pronounced, especially in cases with severe hemodynamic alterations (high pressure in the pulmonary artery and the right side of the heart; Fig. 14.) Only a few patients with very slight circulatory changes had a barely perceptible atrial contraction descent. In the other patients in this group it was very distinct, not only over the right auricular appendage but also all over the right auricular wall (Fig. 13).

The onset of this electrokymographic event took place approximately at the same time in the heart cycle in both the normal controls and the patients with atrial septal defect. The time interval between the beginning of the P-wave in the ECG and the onset of the atrial contraction descent was in most instances longest among the young patients with atrial septal defect. It varied, for instance, between 0.13 and 0.18 sec in the four youngest patients (Fig. 15), who were between 15 and 17 years of age. In the older patients, on the other hand, the atrial contraction descent occurred relatively early (Fig. 16).

In 13 cases of atrial septal defect the duration of the right atrial contraction descent exceeded 0.10 sec and in 12 it was 0.09 to 0.10 sec. The longest time was observed in patients with severe hemodynamic alterations, where, among other signs, the pressure in the right auricle

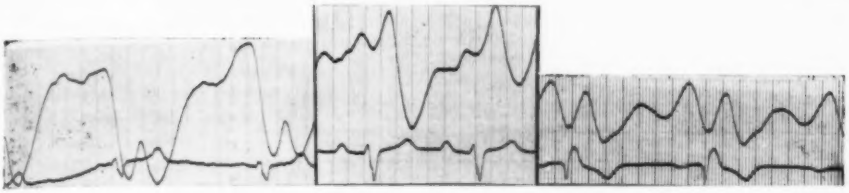


Fig. 14 Fig. 15 Fig. 16

Figs. 14, 15 and 16. Atrial septal defect. Right auricular EKyG. 14) Female, aged 20. Right auricular systolic pressure 15.5 mm Hg. (Mean pressure 13 mm Hg.) Pulmonary artery pressure 35/13 mm Hg. Atrial contraction descent accentuated, duration 0.16 sec. Diastolic plateau and a pronounced rise during late systole and early diastole. Rapid ejection downstroke short. Relative slow cardiac rhythm. 15) Female, aged 17. Normal pressure conditions in right side of heart. Atrial contraction descent normal, but begins uncommonly late, 0.16 to 0.17 sec after onset of P-wave in ECG. 16) Male, aged 35. Normal pressure conditions in right side of heart. Atrial contraction descent starts 0.09 to 0.10 sec after onset of P-wave in ECG.

was increased (Fig. 14). In 5 cases in which the duration was over 0.10 sec, the right auricular mean pressure was more than 10 cm of water. (FOWLER et coll. gives the values 2.1 mm Hg, range 1—4.5 mm Hg for normal right auricular mean pressure, and 5.6 mm Hg, range 2.5—7.0 mm Hg for normal right auricular systolic pressure.)

The mean pressure depends, however, to a certain extent on the length of the cardiac cycle (LITTLE et coll., and others) and is probably only capable of giving vague information regarding the activity of the auricular contraction.

Detailed pressure curves from the right auricle were therefore made in 13 cases of atrial septal defect. A direct correlation between the maximum amplitude of the right auricular contraction pressure and the duration of the right atrial contraction descent is distinctly seen (Diagram 1). Accordingly, these findings indicate that a prolongation of the right atrial contraction descent corresponds to increased right atrial systolic pressure.

Direct divergences from the normal could not be demonstrated with respect to the isometric contraction upstroke; nor were there any signs to indicate tricuspid valve insufficiency in any of the cases.

In some of the patients with atrial septal defect, especially those with severe hemodynamic changes (Fig. 14), the right auricular EKyG had a noticeably short and indistinct rapid ejection downstroke, and a steep rise with a relatively large amplitude during late systole and early diastole. The electrokymographic configuration during the closure of the pulmonary valves, as well as the relative times for this event, were on the whole normal. In a few cases of atrial septal defect with marked circulatory alterations (high pressure in the right ventricle and pulmonary artery and considerable dilatation of the right side of the heart), a delay in

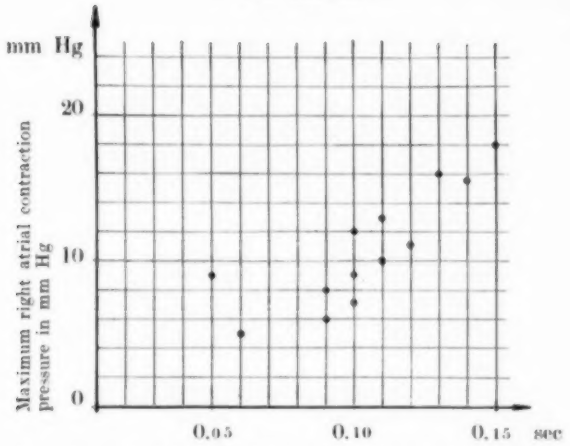


Diagram 1. Relation between maximum right atrial contraction pressure and duration of right atrial contraction descent in 13 cases of atrial septal defect. There is a direct correlation.

the opening of the tricuspid valves was sometimes established electrokymographically. This event occurred, in the most extreme cases, 0.17 to 0.18 sec after the T-wave of the ECG (Figs. 17 and 18 a). This change could sometimes be confirmed by pressure registration in the right auricle (Fig. 18). The hemodynamic grounds for this may be as follows: The tricuspid valves do not open until after the pressure in the right ventricle has dropped below that in the right auricle. In some cases of atrial septal defect, there is a delay before the evening up of the pressure between these two heart chambers occurs at the close of systole, this being the direct cause of the delay in the opening of the tricuspid valves.

In 12 cases of atrial septal defect, a more or less marked tendency toward a relative decrease in the descent of the rapid inflow downstroke and in the ascent of the slow inflow upstroke, with a poorly delineated transition between these events, was observed (Figs. 14 and 17). (An electrokymographic pattern of this type is called 'diastolic plateau' in the remainder of this paper.) Among the 14 oldest patients in the atrial septal defect group, ranging in age from 32 to 51 years, 8 had a diastolic plateau in the right auricular EKyG. Severe enlargement of the right side of the heart was demonstrated in these patients. The right ventricular systolic pressure showed a slight to moderate increase, ranging from 31 to 46 mm Hg.

Right auricular EKyG in valvular pulmonary stenosis

The investigations also included 11 persons with valvular pulmonary stenosis, forming 'the pulmonary stenosis group'. Their ages ranged from 9 to 44 years. Six of

them were subjected to valvotomy by the BROCK method. The diagnosis was established by selective angiocardiography. Right heart catheterization together with blood oxygen analysis and pressure registration was carried out in all cases. In six, a defect in the auricular septum or a shunt between the auricles was demonstrated. Six cases were examined electrokymographically and five were catheterized after the operation.

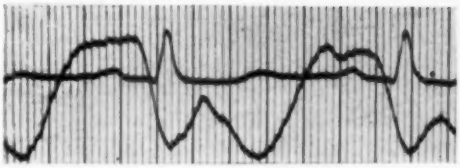


Fig. 17. Female, aged 38. Atrial septal defect. Increased pressure in pulmonary artery, right ventricle and right auricle. Right auricular EKyG. The curve rises steeply in late systole and early diastole. Diastolic plateau.

Variations of the same type as those usually occurring in normal right auricular EKyG were demonstrated in this group also.

Definite pathologic electrokymographic changes were also seen. Right auricular EKyG were, for instance, recorded from a comparatively large sector of the right side of the heart, indicating enlargement of the right atrium in these pulmonary stenosis cases (Fig. 19). The right atrial contraction descent was very distinct, with a relatively large amplitude, in almost all cases. It was most plainly seen in records obtained over the middle and caudal parts of the right borderline, with the patient in a moderate to extreme left anterior oblique position.

The right atrial contraction descent started relatively early in the cardiac cycle, without, however, any directly abnormal divergences being noted (Figs. 19, 20 and 22). The duration of this event was often considerably prolonged, in some instances exceeding 0.20 sec (Fig. 20 a). The value was around 0.11 sec or over in 10 patients and 0.10 sec in one patient, in pre-operative examinations. In the latter patient, no shortening of the duration was noted after valvotomy. The duration was de-

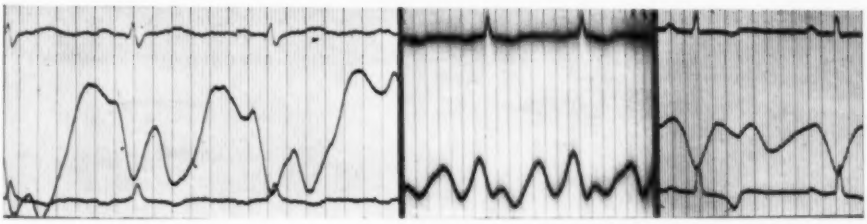
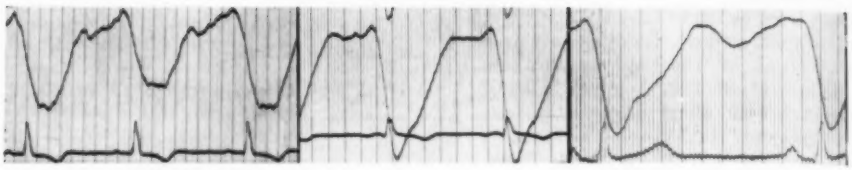


Fig. 18 a Fig. 18 b Fig. 19

Fig. 18. Female, aged 40. Atrial septal defect. a) Right auricular EKyG, b) Right auricular pressure curve. In a) tricuspid valves open 0.15 to 0.17 sec after end of P-wave in ECG, and in b) 0.14 sec. Fig. 19. Male, aged 27. Valvular pulmonary stenosis combined with atrial septal defect. EKyG obtained from right cardiac silhouette directly above diaphragmatic arch with the patient in slightly left anterior oblique position. Typical auricular curve suggesting enlargement of auricle. Atrial contraction descent accentuated, duration 0.16 sec. It starts 0.06 sec after onset of P-wave in ECG.



a b c

Fig. 20. Female, aged 22. Valvular pulmonary stenosis combined with atrial septal defect. Right auricular EKyG. a) Before valvotomy. Atrial contraction descent pronounced, duration 0.23 to 0.24 sec. A steep rise during late systole and early diastole with an indistinct rapid ejection downstroke. Diastolic plateau. b) Four weeks after operation. Atrial contraction descent's duration 0.16 sec. Same pathologic pattern as before intervention. c) Two years after operation. Duration of atrial contraction descent 0.15 sec. Same electrokymographic changes as before valvotomy despite considerable improvement.

creased, however, in 5 of the others in whom the atrial contraction descent was prolonged before the operation. A gradual decrease was observed in 4, in repeated postoperative electrokymographic examinations, but the value did not return to complete normality (Fig. 20).

Detailed pre-operative pressure measurements in the right auricle were carried out in 5 cases in the pulmonary stenosis group. In this group also, there seems to be a direct correlation between the maximum right atrial contraction pressure and the duration of the right atrial contraction descent similar to that demonstrated in the atrial septal defect group.

Postoperative pressure measurements in the right auricle revealed that 4 patients with increased maximum right auricular contraction pressure had a prolonged right atrial contraction descent also. These incidents were normal in one case.

A few pulmonary stenosis patients with concomitant atrial septal defect (Fallot's triad) also had a relatively prominent amplitude of the left auricular appendage contraction descent together with a duration of 0.10 to 0.11 sec (Fig. 21).

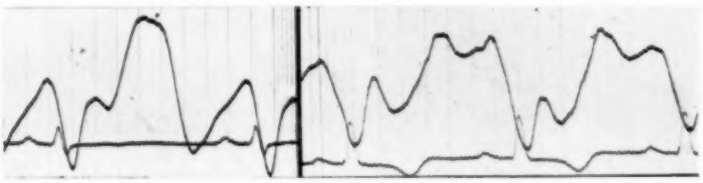


Fig. 21 Fig. 22

Fig. 21. Male, aged 19. Valvular pulmonary stenosis combined with atrial septal defect. Left auricular appendage EKyG. Left atrial contraction descent accentuated; duration 0.10 to 0.11 sec. Fig. 22. Female, aged 31. Valvular pulmonary stenosis. Right auricular EKyG. Isometric contraction upstroke barely perceptible, duration 0.06 sec. Atrial contraction descent very pronounced, lasting till 0.04 sec after R-wave of ECG. Diastolic plateau.

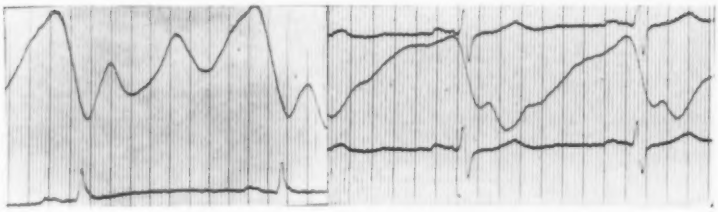


Fig. 23. Male, aged 34. Constrictive pericarditis. Right auricular EKyG. Atrial contraction descent has increased relative amplitude, duration 0.17 sec.

Fig. 24. Male, aged 36. Mitral valve stenosis and insufficiency (diagnosed at operation). Right auricular EKyG. Typical abnormal pattern. Atrial contraction descent's duration 0.14 sec.

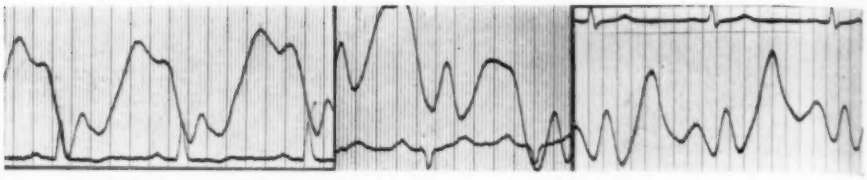
Observations made in the pulmonary stenosis group indicate that there may be an intimate direct correlation between the right atrial contraction pressure and the right atrial contraction descent.

A few cases in this group had a strikingly flattened, short isometric contraction upstroke with an unnaturally long atrial contraction descent continuing beyond the R-wave of the ECG (Fig. 22). The same phenomenon has been demonstrated in left auricular EKyG in mitral valve stenosis (ANDERSSON). This is probably due to the fact that the medially-directed movement of the auricular wall, caused by the auricular contraction, suppresses the laterally-directed movement produced by the isometric contraction.

Changes suggesting tricuspid valve insufficiency were not found in the pulmonary stenosis group. On the other hand, there was in many cases a comparatively steep, prominent rise in the curve during late systole and early diastole while at the same time the rapid ejection downstroke was barely perceptible (Fig. 20). This type of tracing seemed to be connected to some extent with the severity of the cardiac impairment, but it was also observed in three cases at a postoperative examination, despite the fact that the hemodynamic conditions had been improved by the intervention.

The closure of the pulmonary valves was only represented in the pulmonary stenosis group by a slight change in gradient of the upward slope. The protodiastolic phase was not distinguishable in right auricular EKyG in any of the patients in this group. This may have been due to the deformation of the pulmonary valves. The relative times for the closure of these valves and the opening of the tricuspid valves lay within normal limits.

Six of the pulmonary stenosis patients had a more or less marked diastolic plateau (Figs. 20, a, b and c, and 22). All of these showed signs indicating severe cardiac impairment, the right side of the heart being dilated and the right ventricular pressure considerably increased



a b c

Fig. 25. Right auricular EKyG from different cases with right heart stress. a) Fallot's tetrad. b) Fallot's pentad. c) Ventricular septal defect. The atrial contraction descent is accentuated and prolonged in all cases.

(the maximum pressure was 90 mm Hg or more). This electrokymographic change was also observed in a postoperative examination in three cases (see p. 374 and 375).

Discussion

The pathologic right auricular EKyG demonstrated in atrial septal defect and valvular pulmonary stenosis have important features in common. In cases with cardiac lesions of sufficient severity, a more or less distinctive electrokymographic pattern having the following characteristics was observed.

1. Prolonged duration and prominent relative amplitude of the atrial contraction descent. This event may be so accentuated that it even suppresses the isometric contraction upstroke.

2. A comparatively steep, clearly marked rise during late systole and early diastole with a relatively small rapid ejection downstroke.

3. A tendency toward a relative decrease in the descent of the rapid inflow downstroke and in the ascent of the slow inflow upstroke (diastolic plateau).

The last-named phenomenon admittedly occurs as a normal variation in a few cases (see p. 361). In the congenital malformations discussed here, however, this electrokymographic incident was definitely correlated with the intensity of the circulatory and anatomic changes. It is, furthermore, a more frequent occurrence in this material than is normal, being found also in cases with a slow cardiac rhythm (Figs. 14 and 20). These facts may indicate that this electrokymographic phenomenon is a direct pathologic change which is linked to the actual cardiac lesion.

This typical auricular pattern has also been encountered in cardiac diseases other than the congenital malformations investigated in this paper. Electrokymographic records from both right and left auricle may display a more or less distinct diversion of this type if the atrial hemodynamics are altered and the atrium in question is enlarged.

This particular pattern may thus be found in right auricular EKyG in failure of the right side of the heart for the most divergent reasons.

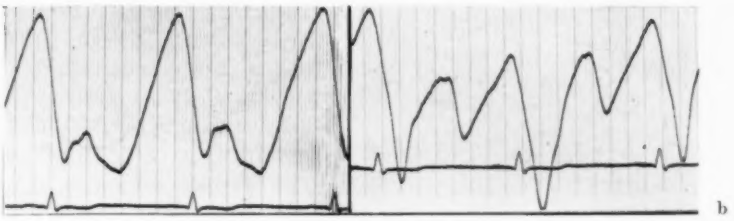


Fig. 26. Female, aged 33. Constrictive pericarditis involving left side of heart (verified at operation). a) EKyG from posterior part of left auricle. b) EKyG from left auricular appendage. Accentuation and prolongation of atrial contraction descent in both EKyG.

It has been encountered by the writer both in acquired cardiac lesions (*e. g.* constrictive pericarditis, Fig. 23; severe mitral valve lesions, Fig. 24; vitium aortae affecting the right side of the heart, Fig. 30 b), and in many cases of congenital vitium cordis in which the circulatory changes had affected the right side of the heart. Fallot's tetrad (Fig. 25 a) and pentad (Fig. 25 b), ventricular septal defect (Fig. 25 c), and idiopathic pulmonal hypertension, may also be mentioned in addition to those already discussed.

The typical pattern can be demonstrated in left auricular EKyG, especially in mitral valve stenosis and constrictive pericarditis affecting the left side of the heart (Fig. 26). This can lead to differential diagnostic difficulties. This pattern may also occur in cases of tumour in the left atrium (Ödman and Marions, to be published; Fig. 27). As has been pointed out earlier, the left atrial contraction descent may be accentuated in Fallot's triad (Fig. 21). This may be explained by the fact that blood is shunted from the right to the left auricle, causing an extra load on the left side of the heart. In patent ductus arteriosus, in which there is also circulation of a large amount of blood through the left side

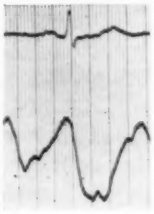


Fig. 27

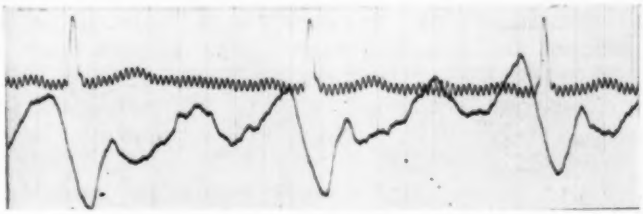


Fig. 28

Fig. 27. Female, aged 53. Tumour in left auricle, diagnosed by angiocardiography and verified at autopsy. Left auricular appendage EKyG. Atrial contraction descent pronounced; duration 0.12 sec. Fig. 28. Male, aged 30. Patent ductus arteriosus, verified at operation. Left auricular appendage EKyG. Atrial contraction descent accentuated and prolonged (duration 0.11 to 0.12 sec).

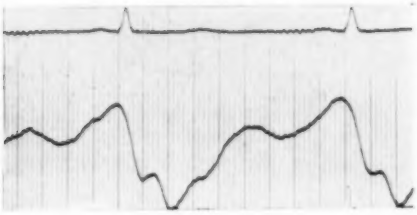


Fig. 29. Female, aged 57. Essential hypertonia. Left auricle enlarged. Left auricular appendage EKyG. Atrial contraction descent pronounced and slightly prolonged. Signs of a diastolic plateau and a steep, pronounced rise during late systole and early diastole.

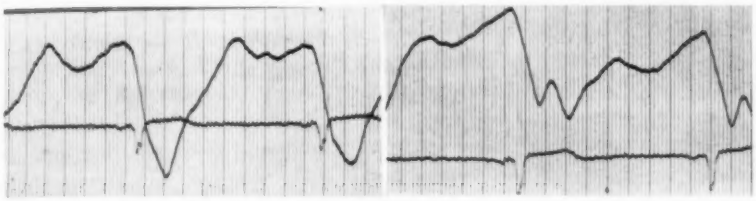
of the heart, this electrokymographic change has also been seen (Fig. 28). The typical electrokymographic pattern may likewise be found in essential hypertonia (Fig. 29), and in both acquired (Fig. 30 a) and congenital aortic stenosis including coarctation of the aorta (Fig. 31).

It would seem logical to expect that this typical pattern in auricular EKyG would be found whenever circulatory disturbances of some intensity affect the auricle under examination. The atrial contraction descent would then seem to be the factor most likely to be affected, seeing that it is influenced even by relatively moderate hemodynamic impairment, long before any decompensation can be detected. (The intimate relationship between the duration of the atrial contraction descent and the maximum auricular contraction pressure has already been demonstrated.) It seems, also, as though a prolongation with a relatively prominent amplitude of the atrial contraction descent diminishes when the circulatory conditions improve (see p. 368).

The other electrokymographic changes, on the contrary, usually make their appearance only in connection with serious circulatory disturbances, in other words, when the auricle in question is greatly dilated. Exceptions to this are, however, known, the atrial contraction descent sometimes remaining normal even when severe hemodynamic alterations are present. The explanation of this is, probably, that the muscles of the auricular wall have become so distended that they cannot achieve adequate contraction (Fig. 32). Apart from this, the principle regulating the auricular contraction activity would seem to be that an increased incitement to active evacuation gives rise to a more powerful contraction (WIGGERS, WOLTER and associates, and others). This manifests itself electrokymographically in the form of prolongation of the atrial contraction descent with a relative increase in its amplitude. Among factors producing heightened activity in the atrial contraction are the following.

1. An unusually large amount of blood circulates through the auricle. This condition prevails in the right auricle in auricular septal defect, for example, and in the left auricle in patent ductus arteriosus.

2. The passive evacuation of the auricle is inadequate. The studies of BAYER et coll., and MCCORD et coll., into right auricular pressure conditions in right ventricular hypertrophy, may be mentioned. These authors noted in connection with different cardiac lesions, that hypertrophy of



a b

Fig. 30. Female, aged 64. Aortic stenosis and insufficiency. Calcified aortic valves. Pulmonary congestion. a) Left auricular appendage EKyG. b) Right auricular EKyG. Typical pathologic pattern in both curves.

the right ventricle may, in itself, hinder the passive filling of the ventricle. Thus, it is not necessary for decompensation to be present before there can be a manifest effect from the ventricle on the atrial hemodynamics. The atrial circulatory disturbances increase still further, of course, when decompensation with increased late diastolic pressure sets in. Among conditions in which this factor is particularly in evidence may be mentioned valvular pulmonary stenosis (effect on right auricle) and aortic stenosis of various types (effect on left auricle). Disturbance of the passive evacuation of the atrium is otherwise probably connected with factor no. 1, and in many instances the effect of both factors together comes into play.

3. Mechanical factors that hinder the passive and active evacuation of the auricle. Constriction of the atrio-ventricular ostium may be mentioned first. This phenomenon is particularly noticeable in the left auricle in mitral valve stenosis, and in the right auricle in tricuspid valve stenosis. Expansive processes that in one way or another obstruct the outflow from the auricle may also be mentioned. In constrictive pericarditis, also, purely mechanical factors probably influence the evacuation of the auricle. Pericarditic adhesions in the auriculo-ventricular groove, for instance,

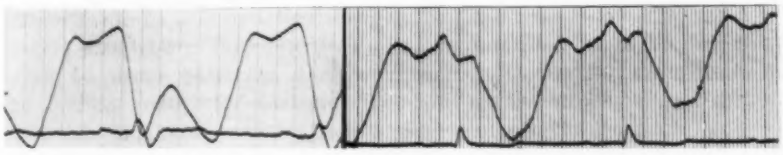


Fig 31 Fig. 32

Fig. 31. Male, aged 42. Coarctation of the aorta. Left auricular appendage EKyG. Typical pattern, indicating an effect on the left auricle. Fig. 32. Female, aged 40. Atrial septal defect. Increased pressure in right auricle, ventricle and pulmonary artery. Considerable enlargement of right side of heart. Right auricular EKyG. Typical pathologic pattern except for the fact that the atrial contraction descent is remarkably small and short.

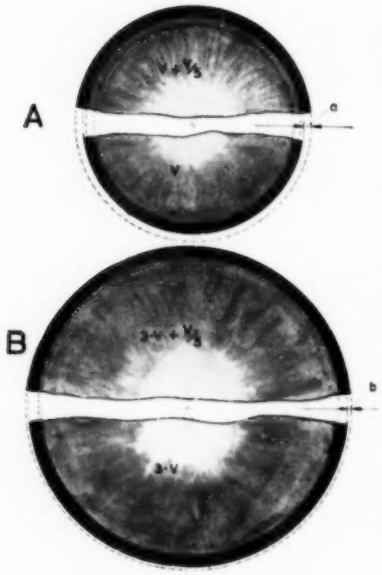


Fig. 33. Two intersected half-spheres, A and B, representing auricles. A's volume = V, B's volume = 3 V (arbitrarily chosen). The displacement of the wall (a and b) in response to an arbitrarily chosen volume-increase $\left(\frac{V}{5}\right)$ is much greater in A than in B.

have proved to be capable of preventing the displacement of the atrioventricular plane during the cardiac cycle (JOHANSSON).

The circulatory genesis of the auricular electrokymographic changes during the passive filling periods has already been discussed by ANDERSSON, and others (see p. 362). The diastolic plateau corresponds to a relatively reduced linear displacement of the auricular wall. In auricles of normal size, this would seem to indicate that the absolute volume changes were relatively small, in other words, that the outflow to the ventricle was decreased and/or the venous inflow increased during the rapid filling phase. During the slow filling period, the opposite conditions would prevail. The linear displacement of the wall is, comparatively speaking, much less pronounced in dilated than in normal-sized auricles, with a volume change of the same magnitude (Fig. 33). This should be borne in mind in a discussion on the hemodynamic grounds for the diastolic plateau. In all the congenital malformations investigated here which displayed this electrokymographic change, the auricle was greatly enlarged (see p. 366 and 369). It is therefore hardly likely that the relative decrease in descent of the rapid inflow downstroke and in ascent of the slow inflow upstroke is directly due to the circulatory changes. The dilatation is probably so considerable that even relatively large volume changes in the auricle during the filling periods caused only a slight displacement of its walls. The significance of the dilatation in this respect receives support from the afore-mentioned observation, namely, that in three cases of valvular pulmonary stenosis in which diastolic plateau had been noted before valvotomy, this electrokymographic change was found to be present almost as before, in postoperative examinations. This observation was made despite the fact that the circulatory conditions had been considerably improved by the surgical intervention. The dilatation of the right auricle, on the other hand, was approximately the same as before the operation (Fig. 20).

The circulatory grounds for the prominent rise during late systole and

early diastole, with a relatively low rapid ejection downstroke, seen in auricular EKyG, have also been discussed by ANDERSSON in his study of mitral valve lesions (see p. 362). The explanation given by this author would in itself presuppose an increased pressure gradient between lung veins and left auricle during these periods. This does not occur in mitral valve stenosis; instead, there is, rather, a parallel rise in pressure in both these vascular areas (BJÖRK et coll.). ANDERSSON does not take up auricular dilatation for discussion. Judging from what has been said previously, however, a relatively large volume increase would probably be required in a distended auricle to produce a relatively large laterally directed displacement of its wall (Fig. 33). Another feature that seems to confute ANDERSSON's explanation is that the electrokymographic change in question persists after the hemodynamic conditions have been improved (see p. 370).

From what can be judged, the electrokymographic phenomenon under discussion does not appear to be directly caused by disturbances in the venous inflow to the atrium. On the other hand, the electrokymographic diversion may possibly be explained by increased influence from movements of adjacent structures, since dilatation plays no part in this. Support for this view is to be found in certain observations obtained at angiocardiographic examinations of the congenital malformations under review. The displacement amplitude of the auriculo-ventricular septum during systole and early diastole appears, in fact, to be especially large in those cases in which serious circulatory impairment has been established. This may conceivably be the reason, in whole or in part, for the relatively prominent lateral displacement of the auricular wall in late systole and early diastole which is usually observed in these patients.

SUMMARY

The normal appearance and chronology of right auricular electrokymograms is first discussed. Findings from right auricular electrokymograms obtained from 43 cases of atrial septal defect and valvular pulmonary stenosis are then presented. When hemodynamic alterations of a certain intensity are present, a typical pathologic pattern is seen in right auricular EKyG. Similar electrokymographic changes may also occur in many other cardiac lesions. The hemodynamic and anatomic causes underlying these electrokymographic changes are discussed.

ZUSAMMENFASSUNG

Das normale Aussehen und die Zeitrechnung bei Elektrokymogrammen des rechten Vorhofes wird zunächst diskutiert. Danach werden die mit Elektrokymogrammen des rechten Vorhofes erhobenen Befunde in 43 Fällen mit Vorhofseptumdefekten und Stenose der Pulmonalisklappen dargelegt. Beim Vorhandensein haemodynamischer Veränderungen gewisser Intensität sieht man hierbei ein typisches pathologisches Bild. Ähnliche elektrokymographische Veränderungen können auch bei vielen anderen Herzerkrankungen auftreten. Die haemodynamischen und anatomischen Ursachen, welche diesen elektrokymographischen Veränderungen zugrunde liegen, werden besprochen.

RÉSUMÉ

L'auteur étudie d'abord la forme et la chronologie normales des électrokymogrammes de l'oreillette droite. Puis il présente les résultats d'électrokymogrammes de l'oreillette droite obtenus dans 43 cas de communication interauriculaire et de sténose valvulaire pulmonaire. Quand les troubles de l'hémodynamique atteignent une certaine intensité, l'EKyG auriculaire droit donne un tracé pathologique typique. Des altérations électrokymographiques semblables peuvent aussi se produire dans de nombreuses autres lésions cardiaques. Les causes hémodynamiques et anatomiques qui sont à la base de ces altérations électrokymographiques sont étudiées.

REFERENCES

Andersson, T.: Electrokymographic examinations in mitral valve disease. Acta radiol. Suppl. 106 (1953).

Bayer, O., Loogen, F. and Wolter, H. H.: Der Herzkatheterismus bei angeborenen und erworbenen Herzfehlern. Georg Thieme, Stuttgart 1954.

Björk, V. O., Malmström, G. and Uggla, L. G.: Left Atrial and Pulmonary "Capillary" Pressure Curves during Valsalva's Experiment. Am. Heart J. 47 (1954), 635.

Boone, B. R., Chamberlain, W. E., Gillick, F. G., Henny, G. C. and Oppenheimer, U. J.: Interpreting the Electrokymogram of Heart and Great Vessel Motion. Am. Heart J. 34 (1947), 560.

Booth, E., Willis, K., Reeves, T. and Harrison, T.: The Right Auricular Electrokymogram of Normal Subjects. Circulation 7 (1953), 916.

Burnstein, J.: The Diastolic Phases of the Cardiac Cycle in Man. Am. J. Physiol. 65 (1923), 158.

Dack, S. and Paley, D.: Electrokymography. II. The Great Vessels and Auricular Electrokymograms. Am. J. Med. 12 (1952), 447.

Deutsch, E., Gmachl, E., Schachinger, H., Siedek, H. and Wenger, R.: Die Elektrokymographie. Ztschr. f. Kreislaufforsch. 40 (1951), 129.

Dussaillant, G., Lessandi, H. and Lepe, A.: Applications cliniques de la méthode électrokymographique. Acta cardiol. 7 (1952), 473.

Engström, B., Kjellberg, S. R. , Persson, L. and Rudhe, U.: Some aspects of the use of electrokymography in cardiac investigation. Acta radiol. 31 (1949), 435.

Fowler, N. O., Westcott, R. N. and Scott, R. C.: Normal Pressure in the Right Heart and Pulmonary Artery. Am. Heart J. 46 (1953), 264.

Grishman, A., Kroop, I. G., Steinberg, M. F. and Dack, S.: Presystolic Pulsations of the Liver in the Absence of Tricuspid Disease. Am. Heart J. 40 (1950), 731.

Heyer, H. and Boone, B.: The Present Status of Electrokymography. A Review. Am. Heart J. 44 (1952), 458.

Holmgren, B.: The movements of the mitro-aortic ring recorded simultaneously by cineroentgenography and electrocardiography. Acta radiol. 27 (1946), 171.

Johansson, L.: Personal communication 1955.

Lagerlöf, H., Holmgren, A. and Werkö, L.: Tidsrelationerna mellan hjärtats elektriska, mekaniska och akustiska impulser hos människa. (Swedish.) Nord. Med. 42 (1949), 1422.

Little, R. C., Opdyke, D. F. and Hawley, J. G.: Dynamics of Experimental Atrial Septal Defects. Am. J. Physiol. 158 (1949), 241.

Long, J. H.: Correlation of the Border Motion of the Heart and Great Vessels as Recorded by the Electrokymograph with Intracardiac Pressure Changes. Proceedings of the First Conference of Electrokymography (1950), 29.

Luisada, A. A.: Atrial Phenomena. Proceedings of the First Conference of Electrokymography (1950), 53.
Luisada, A. A. and Fleischner, F. G.: Dynamics of the Left Auricle in Mitral Valve Lesions. Am. J. Med. 4 (1948), 791.
— Simultaneous Fluorocardiography and Recording of Intracardiac Pressure. Proc. Soc. Exper. Biol. & Med. 70 (1949), 730.
McCord, M. C., Komesu, S. and Blount, S. G.: The Characteristics of the Right Atrial Pressure Wave Associated with Right Ventricular Hypertrophy. Am. Heart J. 45 (1953), 706.
McKinnon, J. and Friedman, B.: Electrokymographic Studies of the Left Atrium in Normal and Diseased Hearts. Circulation 2 (1950), 572.
Mednick, H., Schwedel, J. B. and Samet, P.: Electrokymographic Studies of the Normal Cardiac Cycle. Circulation 2 (1950), 250.
Rushmer, R. F. and Crystal, D. K.: Changes in Configuration of Ventricular Chambers during the Cardiac Cycle. Circulation 4 (1951), 211.
Rushmer, R. F. and Thal, N.: The Mechanics of Ventricular Contraction. A Cinefluorographic Study. Circulation 4 (1951), 219.
Salans, A. H., Schack, J. A. and Katz, L. N.: Correlations of Simultaneously Recorded Electrokymograms and Pressure Pulses of Human Heart and Great Vessels. A Preliminary Report. Circulation 2 (1950), 900.
Soloff, L. A., Zatuchni, J. and Stauffer, H.: The Atrial Border Electrokymogram in Mitral Regurgitation. Circulation 5 (1952), 96.
Sundberg, C. G.: Kymographische Untersuchung eines Herzens mit verkalktem Annulus fibrosus. Acta radiol. 22 (1941), 834.
Westermark, N.: A study of the cardiac movements simultaneously recorded by roentgen-cinematography and electrocardiography. Acta radiol. 22 (1941), 393.
— Circulation through the heart, the big vessels and the pulmonary circulation, simultaneously recor[illegible] by cinematography and electrocardiography. Acta radiol. 23 (1942), 473.
Willis, K., Eddleman, E. E., Acker, J. K., Poulos, E. and Heyer, H. E.: Variations in the Duration of Phases of the Cardiac Cycle in Normal Hearts as Studied by the Electrokymograph. Am. Heart J. 40 (1950), 485.
Wiggers, C. J.: Studies on the Consecutive Phase of the Cardiac Cycles and the Criteria for Their Precise Determination. Am. J. Physiol. 56 (1921), 415.
— The Pressure Pulses in the Cardiovascular System. Longmans, Green and Co., London, New York, Toronto 1928.
— Physiology in Health and Disease. Ed. 5. Lea and Febiger, Philadelphia 1949.
— Circulatory Dynamics. Grune and Stratton, New York 1952.
Wolferth, C. and Margolies, A.: Movements of Roentgen-opaque Deposits in Heart Valve Areas. Am. J. M. Sc. 197 (1939), 197.
Wolter, H. H., Bayer, O., Loogen, F. and Rippert, R.: Die sogenannte Pulmonalkapillardruckkurve und ihre Beziehung zur Druckkurve des rechten und linken Vorhofs. Cardiologia 22 (1953), 319.

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THE VALUE OF PELVIC ARTERIOGRAPHY IN THE DIAGNOSIS OF MOLE AND CHORIONEPITHELIOMA

by

Ulf Borell, Ingmar Fernström and
Axel Westman

The diagnosis of a mole or a chorionepithelioma often presents considerable difficulty. The trophoblastic cells of these placental tumours penetrate and destroy the walls of the uterine blood vessels, resulting in the formation of blood-filled spaces in the wall of the corpus uteri. Excessive vascularity of the uterus is an additional characteristic feature of these cases. The assumption can be made that the findings on arteriography of the uterine arteries are characteristic enough to be diagnostic. In order to investigate whether this is indeed so, the anatomy of the uterine arteries was studied by pelvic arteriography and radiography of operation specimens after injection of opaque medium into the arteries in 2 cases of mole and 1 case of chorionepithelioma (for details of the technique see FERNSTRÖM 1955). Extracts of the histories of these cases are given below.

Case Reports

Case 1 (Chorionepithelioma). The patient, aged 36, underwent curettage on account of incomplete abortion in the third month of pregnancy. Microscopy of the curettings revealed hydatidiform mole. Bleeding continued and vaginal metastases developed, obviously from a chorionepithelioma. Hysterectomy was performed.

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Macroscopic examination of the operation specimen revealed a lobulated tumour of the uterus, which originated in the fundus and bulged into the uterine cavity (Fig. 1 a). A roentgenogram of the operation specimen was taken after injection of opaque medium into the arteries; the only abnormality revealed was the presence of spaces continuous with the arteries within the tumour (Fig. 1 b).

Case 2 (Mole destruens). The patient, aged 41, produced a hydatidiform mole in the fourth month of pregnancy and was therefore subjected to curettage. As vaginal bleeding continued, and in order to investigate whether this was caused by retained portions of the mole, she was examined by pelvic arteriography on two occasions. The first arteriographic examination was carried out seven days after curettage, and the second nine days later. The first radiographic examination revealed a vascular area in the uterine wall, which at the second examination was found to have increased in size (Fig. 2). Next day hysterectomy was performed. Macroscopic examination of the operation specimen revealed a tumour which originated in the uterine wall in the vicinity of the fundus and bulged into the uterine cavity. Microscopy showed it to be a mole destruens (Fig. 3 a). A roentgenogram of the operation specimen was taken following injection of opaque medium into the arteries (Fig. 3 b). Several small spaces, which were continuous with the arteries, were found within the tumour. A remarkably large number of narrow arteries following an irregular course within the tumour was an additional finding.

Case 3 (Hydatidiform mole). The patient, aged 40, was in the third month of pregnancy. She was admitted to hospital on account of repeated and profuse vaginal bleeding. As it was assumed that the entire ovum had been expelled, curettage was not considered to be indicated. Six weeks later, however, curettage was carried out on account

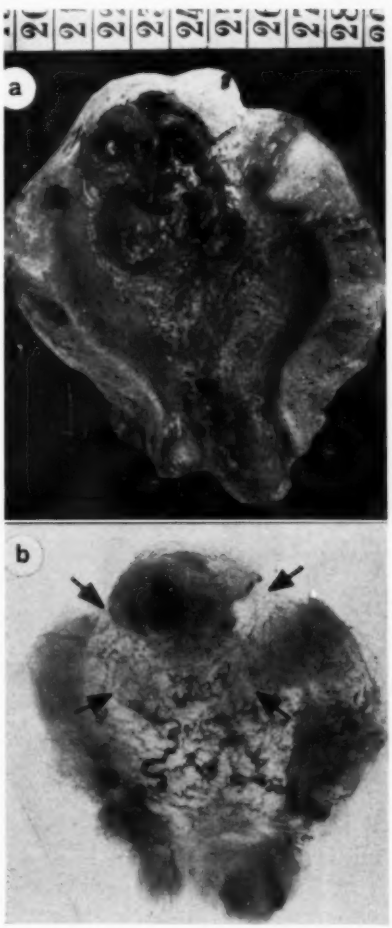

Fig. 1. Operation specimen Case 1 (*chorionepithelioma*). a. Photograph of uterus with lobulated tumour originating in the fundus and posterior corporeal wall. b. Roentgenogram following arterial injection. Intramural blood vessels showing normal tortuosity. The arrows point to the site of the tumour. A few opacified spaces within the tumour.

of recurrence of bleeding, and yielded a large amount of tissue. Microscopy of the curettings revealed a hydatidiform mole showing marked proliferation and polymorphism of the trophoblastic cells. After the curettage the patient was symptom-free. The microscopic findings, however, led to examination by pelvic arteriography, which was carried out two weeks after the curettage. The arteriograms showed enlargement of the uterus and a remarkably large number of blood vessels at the level of the fundus. The appearances were consistent with the presence of retained portions of mole in the uterine wall (Fig. 4). Four days after pelvic arteriography, hysterectomy was performed. Macroscopic examination of the operation specimen revealed a lobulated tumour, which originated in the uterine wall in the vicinity of the fundus and bulged into the uterine cavity (Fig. 5 a). The tumour was made up partly of typical molar vesicles containing clear fluid, and partly of bluish fragments of tissue. Microscopy revealed the tumour to be a hydatidiform mole showing marked proliferation of the trophoblastic cells. A roentgenogram of the operation specimen was taken after injection of opaque medium into the arteries (Fig. 5 b). A remarkably large number of narrow arteries fol-

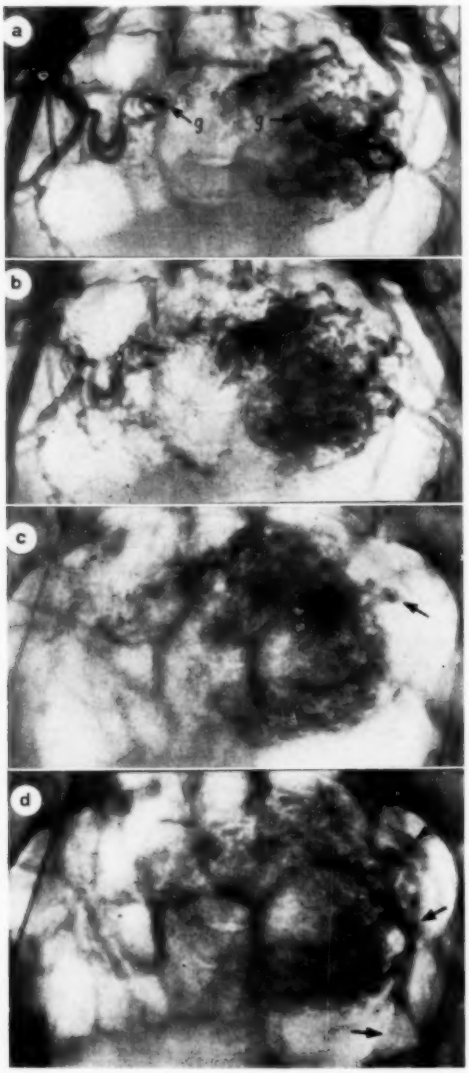

Fig. 2. Arteriogram Case 2 (*mole destruens*). The major part of the tumour involved the left half of the uterus. a. Immediately following completion of the injection of opaque medium. Both uterine arteries clearly visible (g = uterine artery along lateral margin of uterus). Numerous intramural blood vessels beginning to opacify in the left half of the uterus. b. 1.5 sec later. Numerous blood vessels in the left half of the uterus, only a few intramural vessels in the right half. c. 3 secs later. Still a large quantity of contrast in the left half of the uterus, most of it appearing to fill small spaces and draining veins. The arrow points to one of the larger veins. d. 3 secs later. Less contrast in the left half of the uterus. The arrows point to large veins in the left lateral part.

lowing an irregular course, and several spaces continuous with the arteries, were visible within the tumour.

Discussion

Pelvic arteriography revealed such characteristic changes in the uterine blood vessels in the two cases of mole presented that the appearances enabled the correct diagnosis to be made. A large number of blood vessels and small opacified areas within the tumour were characteristic features of the arteriograms. In addition the opaque medium was seen to pass rapidly into large veins which suggested the presence of arteriovenous shunts. The present writers have hitherto not observed these appearances in other types of uterine tumour or in cases of normal intra-uterine pregnancy; nor have they been encountered during the puerperium or after abortion.

Pelvic arteriography was unfortunately not carried out in the case of chorionepithelioma presented but roentgenography of the operation specimen after injection of opaque medium into the arteries revealed the same characteristic changes in the anatomy of the uterine blood vessels as in the two cases of mole. The assumption may therefore be made that the findings on pelvic arteriography would also have been diagnostic in this case.

From the observations made in the cases presented it may reasonably be assumed that pelvic arteriography may be of value 1) in the

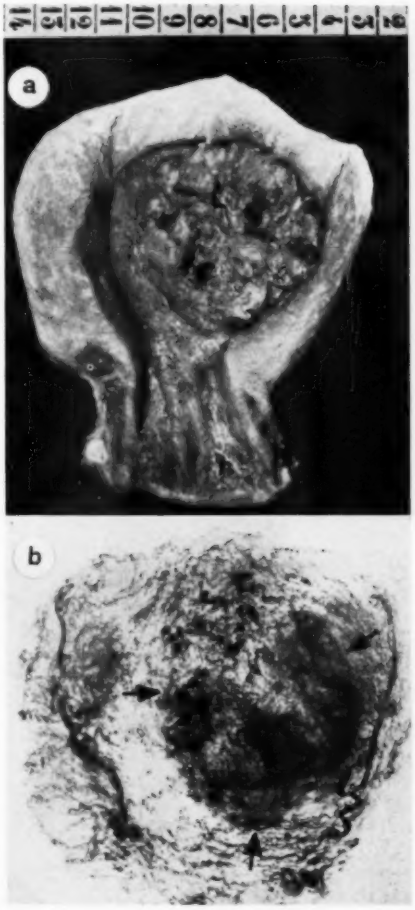

Fig. 3. Operation specimen Case 2. a. Photograph of uterus with lobulated tumour originating in the left postero-lateral part of the corpus and bulging into the uterine cavity. b. Roentgenogram following arterial injection. Numerous intramural blood vessels, showing normal tortuosity, in the uterine wall. The arrows point to the site of the tumour. A remarkably large number of narrow arteries, following an irregular course, and small opacified areas are seen within the tumour.

diagnosis of different types of mole or chorionepithelioma, 2) in the follow-up of cases, where the development of a new tumour is suspected following evacuation of the uterus carried out on account of the presence of a mole.

As the macroscopic and particularly the microscopic appearances of placental tumours vary greatly, no doubt a good many cases will not show the radiographic appearances described, and therefore will not be diagnosed by pelvic arteriography. Nevertheless, it was considered justified to draw attention to the possible value of this procedure in the diagnosis of these tumours. Hydatidiform mole and chorionepithelioma are extremely rare, only a very small number of cases being generally seen in any particular clinic. The elucidation of the value of pelvic arteriography in the diagnosis of these conditions would be greatly assisted if the procedure were more widely adopted in the routine examination, and a larger number of results thus made available for study.

Fig. 4. Arteriogram Case 3 (*hydatidiform mole*). The tumour originated posteriorly in the fundus. a. Immediately following completion of the injection of opaque medium. Both uterine arteries are clearly visible (g = uterine artery along lateral margin of uterus). b. 1.5 sec later. Numerous intramural blood vessels within the fundal wall. c. 3 secs later. A large amount of opaque medium within the fundal wall; most of it probably filling spaces and veins. d. 3 secs later. Now, only traces of the opaque medium within the fundal wall. Several wide veins along the lateral margin of the uterus. The arrows point to these veins on the left side.

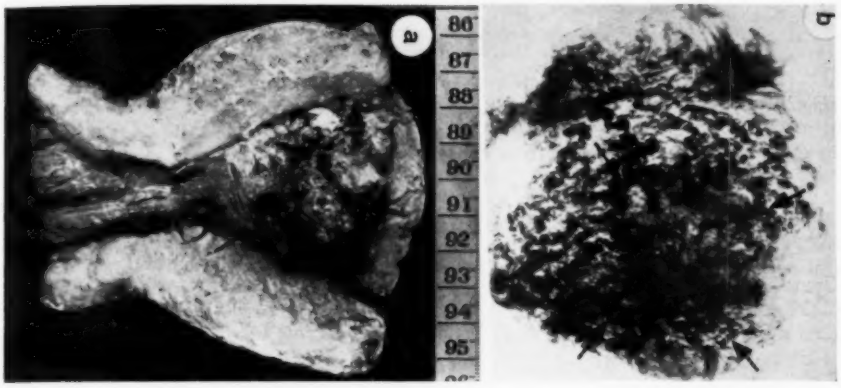

Fig. 5. Operation specimen Case 3. a. Photograph of uterus with the tumour exposed; this is a lobulated tumour originating in the posterior fundal wall and bulging into the uterine cavity. b. Roentgenogram following arterial injection. Numerous intramural blood vessels showing normal tortuosity in the uterine wall. Arrows point to the tumour, which is very vascular.

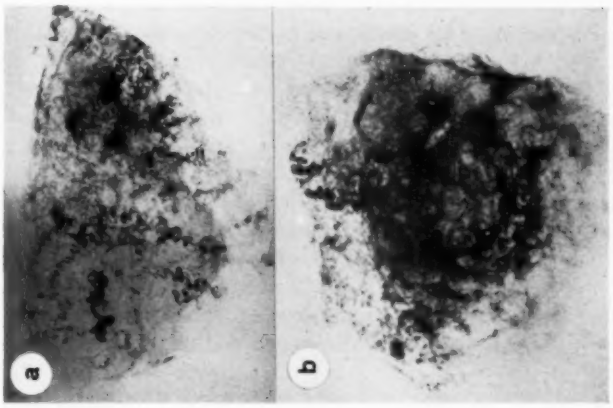

Fig. 6. a. Roentgenogram of normal uterine wall dissected from operation specimen in Case 3. All the intramural arteries are symmetrically arranged and tortuous. b. Roentgenogram of tumour dissected from above operation specimen. Numerous narrow blood vessels following an irregular course, and several small spaces are present.

SUMMARY

Observations made on pelvic arteriography and roentgenography of operation specimens after arterial injection in 1 case of hydatidiform mole, 1 case of mole destruens, and in 1 case of chorionepithelioma, have shewn that pelvic arteriography can be of value in the diagnosis of these conditions.

ZUSAMMENFASSUNG

Beobachtungen bei der Bäckenarteriographie und der Röntgenuntersuchung von Operationspräparaten nach arterieller Injektion in 3 Fällen, einem mit hydatidiformer Mole, einem mit destruierender Mole und einem mit Chorionepitheliom, haben gezeigt, dass die Bäckenarteriographie für die Diagnostik dieser Zustände wertvoll sein kann.

RÉSUMÉ

L'étude de l'artériographie pelvienne et de la radiographie des pièces opératoires après injection artérielle dans un cas de môle hydatiforme, un cas de môle disséquante et un cas de chorio-épithéliome a montré que l'artériographie pelvienne peut être intéressante pour le diagnostic de ces affections.

REFERENCE

FERNSTRÖM, I.: Arteriography of the uterine artery. Acta radiol. Suppl. 122 (1955).

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ROENTGENOGRAPHY FOLLOWING LOBECTOMY OR PNEUMONECTOMY FOR BRONCHIECTASIS

Analysis of 103 Cases

by

C. E. Gudbjerg

Due to the enormous developments in thoracic surgery during recent years, the radiologist is with an ever-increased frequency confronting problems related to changes in the chest roentgenogram following operations on the thorax. He must therefore be familiar with the radiologic characteristics of both the normal and abnormal postoperative course, particularly because the changes seen are often the first manifestations of complications, which it is of the greatest importance to recognize at the earliest possible time.

The present study is an analysis of the roentgenologic aspects of the postoperative course in 88 patients, who during the years 1942 to 1953 inclusive were subjected to operations for bronchiectasis not due to tumour, lung abscess, or tuberculosis.

The sex and age distributions are shown in Table 1. A total of 103 operations were performed; the types of operation used in the various cases are given in Table 2.

Roentgenograms were taken on the first postoperative day, while the patients were lying in bed, and when possible also in the sitting position; in most cases they were also obtained daily during the following week but after that time only when indicated by the clinical condition. Roentgenograms were also obtained just before discharge and at subsequent follow-up examinations from a few months to several years after the operation.

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Obviously, the primary disease plays an important part in the postoperative course as reflected by the chest roentgenograms. The possibility of infection and, hence, the risk of intrathoracic complications are greater in an operation for bronchiectasis than in cardiac surgery, for example.

Table 1

Sex and age distribution of 103 cases of bronchiectasis treated with lobectomy or pneumonectomy

Age, in years	6–15	16–30	31–45	46–63	Total
Males	9	10	16	13	48
Females	5	25	20	5	55
Total	14	35	36	18	103

Table 2

Types of operation in 103 cases of bronchiectasis

Age, in years	6–15	16–30	31–45	46–63	Total
Types of operation					
Pneumonectomy	1	5	6	6	18
Lobectomy					
R. U. L.	0	0	1	0	1
R. M. L.	3	4	7	1	15
R. L. L.	0	5	4	0	9
R. M. L. + R. L. L.	2	6	3	4	15
R. M. L. + R. U. L.	1	0	0	0	1
L. U. L.	0	0	1	1	2
L. L. L.	2	7	5	5	19
L. L. L. + lingula	3	5	7	1	16
Segmental resection, including lingulectomy	2	3	2	0	7
Total	14	35	36	18	103

Roentgenographic appearance after uncomplicated lobectomy or segmental resection

The chest roentgenogram taken on the first postoperative day following lobectomy or segmental resection shows a slight flattening of the chest wall. The remaining lung tissue usually fills up the thoracic cavity, but a narrow band representing a pneumothorax along the lateral chest wall, or over the apex, should not be considered abnormal and has no pathologic significance. Particularly following segmental resection, in which the lung surface has been injured, simple pneumothorax as an isolated phenomenon must be regarded as normal and relatively trivial.

After all operations on the lung, changes possibly due to effusion and hyperaemia, to minor haemorrhages consequent to manipulations

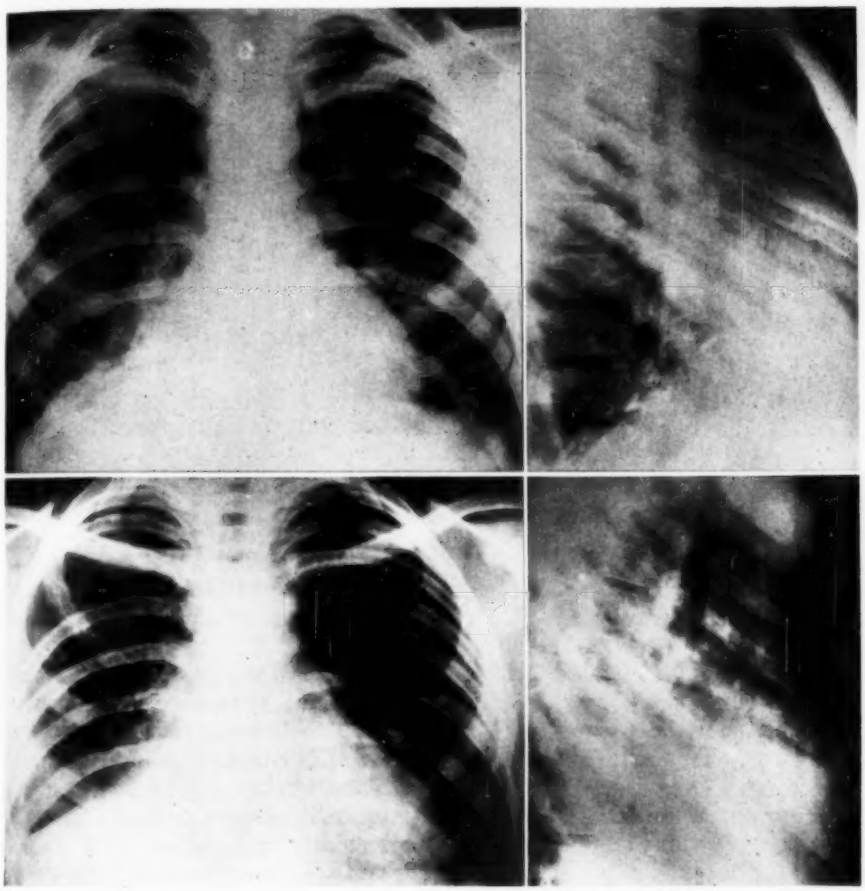

Fig. 1. Boy. Right middle and lower lobectomy. *Top left* and *right:* before operation, erect. Slight consolidation of right lower and middle lobes, which are partially atelectatic. Left lung normal. *Bottom left* and *right:* eighth postoperative day, erect. Fifth rib on the right side resected; no pneumothorax. Moderate thickening of the pleura basally and along the chest wall; some pleural fluids. Slightly increased density of the parenchyma on the right side.

of the lung during the operation, and, to some extent, to accumulation of bronchial secretions, are seen. The densities will usually disappear in the course of 2 to 3 weeks, and the lung will then again become clear. In addition, a varying amount of fluid may appear in the pleura. The accumulation of fluid, which is a normal consequence of operative injury,

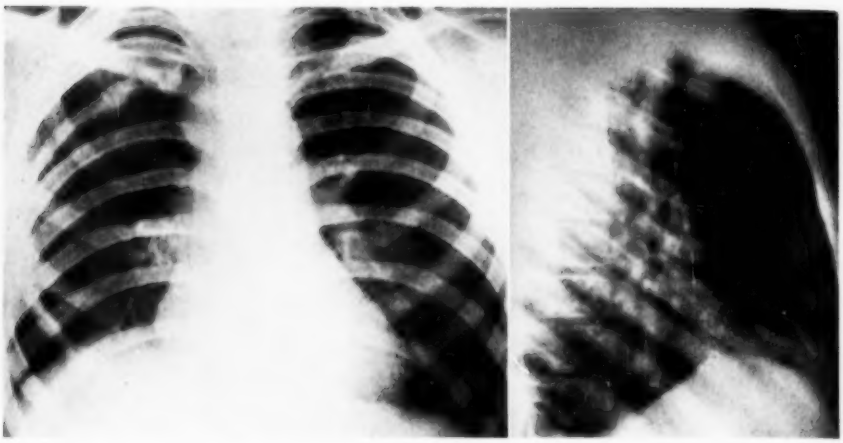

Fig. 2. Same case as Fig. 1. Seven months after operation, erect. Complete regeneration of the resected rib. Slight pleural changes along the right dome of diaphragm, otherwise normal.

consists of blood with some admixture of pleural exudate. The amount present is relatively small owing to the employment of basal drainage. The mediastinum is not displaced.

The diaphragm is slightly flattened; there is little elevation and the mobility is but slightly reduced. As the basal fluid is absorbed, the density will clear, and on the patient's discharge 2 to 3 weeks later, the only radiologic changes present are the resected rib and minor pleural thickening. The resected rib will to a considerable extent regenerate, whereas distinct pleural changes will practically always persist although they may become less conspicuous, particularly in children.

Roentgenographic appearances after uncomplicated pneumonectomy

The radiologic changes seen after pneumonectomy are obviously quite different from those following lobectomy. Although the details of the operative technique is outside the scope of this paper, it is necessary to recall that the surgeon checks the intrathoracic pressure immediately after the operation with a view to maintaining the mid-position of the mediastinum. Accordingly, the roentgenogram does not primarily show any significant mediastinal displacement, but over most of the operated side there is considerable opacity due to blood, lymph, and pleural fluid. Drainage is not used in pneumonectomy in this hospital, because the aim is to ensure that the thoracic cavity fills up. During the first postoper-

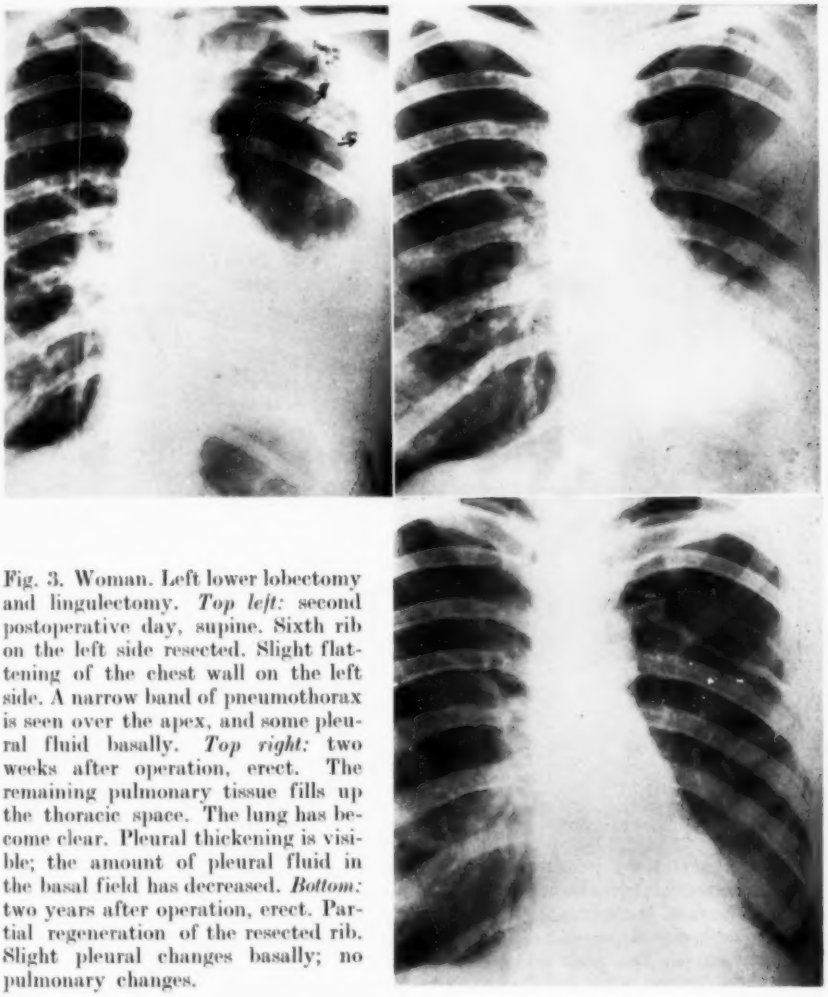

Fig. 3. Woman. Left lower lobectomy and lingulectomy. *Top left:* second postoperative day, supine. Sixth rib on the left side resected. Slight flattening of the chest wall on the left side. A narrow band of pneumothorax is seen over the apex, and some pleural fluid basally. *Top right:* two weeks after operation, erect. The remaining pulmonary tissue fills up the thoracic space. The lung has become clear. Pleural thickening is visible; the amount of pleural fluid in the basal field has decreased. *Bottom:* two years after operation, erect. Partial regeneration of the resected rib. Slight pleural changes basally; no pulmonary changes.

ative days the amount of fluid increases, and to prevent marked displacement of the mediastinum it may be necessary to tap the former. It is therefore important to follow further developments by daily roentgen examinations.

In the course of two weeks or so the fluid begins to organize, and pleural thickening develops along the thoracic wall, which is flattened,

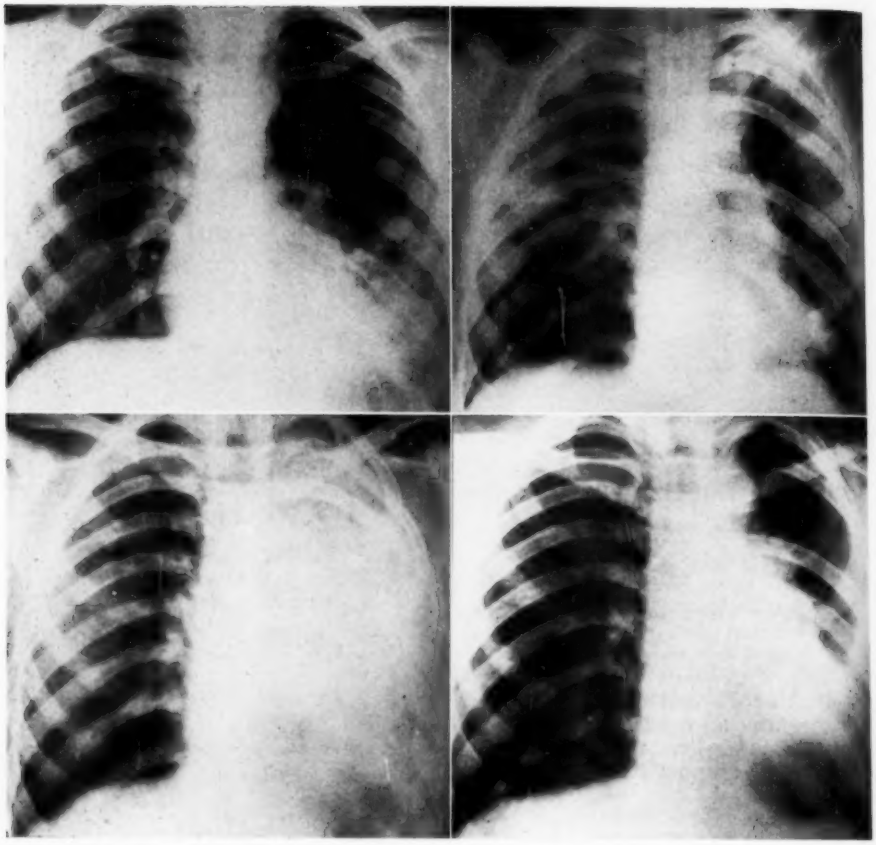

Fig. 4. Girl. Left lower lobectomy and lingulectomy. *Top left:* before operation, erect. Distinct honeycomb-like densities basally in the left lung and moderate pleural changes. The upper part of the left lung and the entire right lung normal. *Top right:* first postoperative day, dorsal position. Fifth rib on the left side resected. Drain inserted. No pneumothorax. No free pleural fluid. *Bottom left:* one week after operation, erect. Free pleural fluid present after the drain has been removed. Heart and trachea slightly displaced towards the left. Pulmonary tissue partly atelectatic. *Bottom right:* two weeks after operation, erect. The densities have cleared. Pleural thickening persists basally; no atelectasis.

and some elevation of the diaphragm occurs. The primary picture of seropneumothorax now changes into one of fibrothorax, and after the lapse of a few months the organization of the effusion has usually become complete. The final picture following pneumonectomy shows pronounced

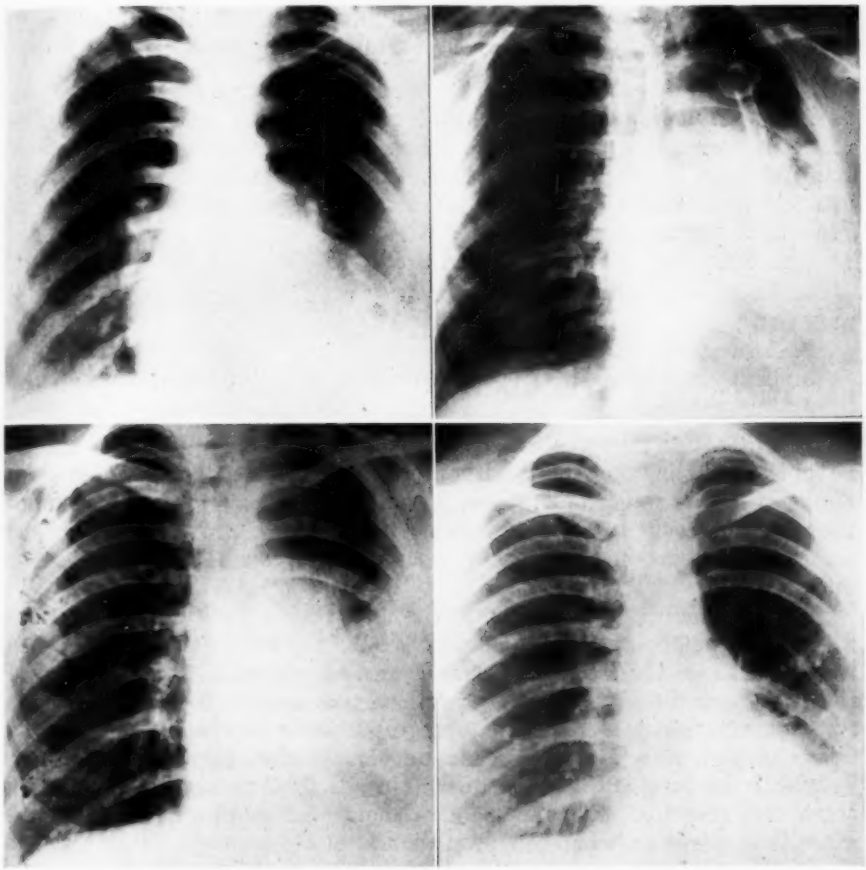

Fig. 5. Woman. Left lower lobectomy and lingulectomy. *Top left:* first postoperative day, supine. Seventh rib on the left side resected and drain inserted. No pneumothorax. Slight opacity at the base. *Top right:* fourth day after operation, supine. Mediastinal displacement towards the left due to partial atelectasis. An additional drain has been inserted; no pneumothorax. *Bottom left:* two weeks after operation, erect. Incipient clearing of the pulmonary pattern. Some basal opacity persists. *Bottom right:* two years after operation, erect. Partial regeneration of the resected rib. Pronounced pleural changes at the left base. Right lung normal.

flattening of the thorax, elevation of the diaphragm, and diffuse opacity over the operated side with some mediastinal displacement to that side as well as compensatory emphysema in the contralateral lung.

Roentgenographic appearances of complications following lobectomy or pneumonectomy

The roentgenographic appearances of postoperative complications are so intimately related to the clinical condition that a survey must be concerned with the clinical rather than the purely radiologic aspects of the problems. However, the radiologist must recognize the postoperative complications which may occur, because roentgen examinations are of decisive importance in their early detection.

The complications of operation are:

1. Failure of adequate expansion (after lobectomy or segmental resection);
2. Atelectasis;
3. Empyema associated or unassociated with bronchial fistula, and
4. Pneumonia.

1. Failure of adequate expansion. A narrow band of pneumothorax as an isolated phenomenon is without clinical importance and will rapidly clear up in the majority of cases. A more pronounced degree of pneumothorax is scarcely in itself of clinical importance, provided it does not occur in association with other complications, such as atelectasis or empyema.

The volume of resected lung tissue plays a certain part in the development of a postoperative pneumothorax. Thus, among the 32 patients in whom more than one lobe was removed, complete re-expansion of the lung immediately after the operation was seen in 9 cases, while the same observation was made in 23 out of 46 cases in which only one lobe was removed. Special factors come into play after segmental resection in which the lung surface has been injured. Of 7 patients subjected to segmental resection, full expansion without pneumothorax immediately after the operation was seen only in one.

In 33 otherwise uncomplicated cases, the lung was fully expanded on the first postoperative day. In 11 cases, of which nine were otherwise uncomplicated, complete expansion occurred within the first week after operation. In another 12 cases, five of which were uncomplicated, complete expansion was seen in the course of two weeks. In 4 patients in whom the postoperative course was otherwise uneventful, a pneumothorax persisted for 21, 25, 30, and 50 days, respectively. In 23 cases complicated by atelectasis or empyema the expansion time varied from 6 weeks to 8 months. Two patients died during the early postoperative period of other complications; both had pronounced pneumothorax.

In recapitulation, it may be said that complete expansion immediately after the operation occurred in 39 per cent of cases, while a minor, isolated, and otherwise insignificant pneumothorax which rapidly dis-

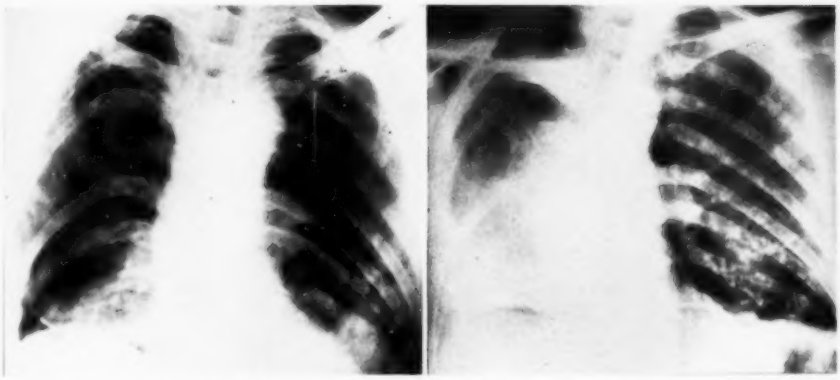

Fig. 6. Man. Right middle and lower lobectomy. *Left:* first postoperative day, supine. Sixth rib on the right side resected. Hood-shaped pneumothorax is visible, but no atelectasis or effusion. Small lobular atelectases at left base. *Right:* fourth postoperative day, sitting. Flattening of the chest wall and retraction of the mediastinum to the right, due to atelectasis.

appeared, was observed in 21 per cent. Failure of adequate expansion associated with postoperative atelectasis or empyema was seen in 40 per cent of cases; the delayed re-expansion was due to these complications.

2. Atelectasis. The development of postoperative atelectasis must be regarded as one of the most serious complications. Atelectasis is dangerous, *inter alia*, because of the resultant incomplete oxygenation of the blood and the hazards of infection and pneumonia. In addition, postoperative atelectasis may be a causative factor in the development of further bronchiectases.

The classic roentgenologic picture is not invariably seen in atelectasis occurring during the first days following thoracic surgery. The diagnosis may be extremely difficult, and in the differential diagnosis of atelectasis from pleural fluid, puncture may be necessary. Repetition of the roentgen examination at intervals of a few hours is often of great value.

It is not the purpose of this paper to give a detailed report of the individual cases. Postoperative atelectasis was demonstrated in 14 cases in the entire series of 85 lobectomies.

Five of these patients were between the ages of 8 and 11 years, four between 19 and 30, while the last five patients were 35, 42, 44, 50, and 58 years of age respectively. In nine cases atelectasis developed within the first 24 hours after operation, in four cases within the first 4 days, and only in one case as late as on the 7th postoperative day. In four patients the atelectasis was complete, as all the remaining pulmonary

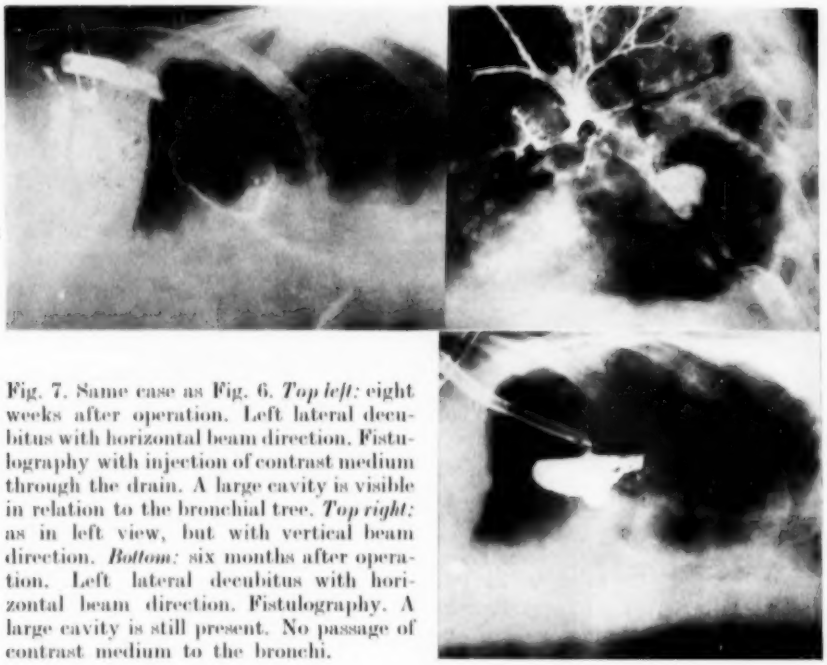

Fig. 7. Same case as Fig. 6. *Top left:* eight weeks after operation. Left lateral decubitus with horizontal beam direction. Fistulography with injection of contrast medium through the drain. A large cavity is visible in relation to the bronchial tree. *Top right:* as in left view, but with vertical beam direction. *Bottom:* six months after operation. Left lateral decubitus with horizontal beam direction. Fistulography. A large cavity is still present. No passage of contrast medium to the bronchi.

tissue on the operated side had collapsed. The atelectasis was lobar in three cases and lobular in the remaining seven. In most cases, the atelectasis was overcome by bronchoscopic suction in the course of a few days.

In two patients — a boy, aged 11, and a woman, aged 26 — it proved impossible to make the collapsed lung tissue re-expand, for which reason it became necessary to subject the patients to further operation on the 22nd and 25th postoperative day, respectively. In both cases there was atelectasis of the left upper lobe, and both patients had previously been operated on for bronchiectasis on the same side, so that the second lobectomy actually amounted to pneumonectomy.

3. Empyema. The roentgenographic appearance of empyema, both in the large diffuse and smaller encapsulated varieties, is well known. In the majority of cases, empyema develops in association with a bronchial fistula. The demonstration of such a fistula is primarily a clinical matter; later it may be revealed by fistulography. However, only in seven cases was it possible to demonstrate the entry of contrast medium from the empyema cavity into the bronchial tree. More or less stubborn empy-

emata, in which fistulography failed to reveal bronchial fistulae, were present in 18 cases.

Both empyema and bronchial fistula are most common in middle or late life and are practically never encountered in children. Of the seven patients with roentgenographically demonstrable bronchial fistula, the youngest was 33 years and the oldest 58 years, while the average age of the patients was 43.

4. Pneumonia. Pneumonia was found to be a relatively infrequent but dangerous complication. Among 18 cases of pneumonectomy, postoperative pneumonia occurred in three, all of which terminated fatally. Among 85 cases of lobectomy, postoperative pneumonia developed only in two, one of which ended in death.

Conclusions

A survey of the primary roentgenographic changes in the chest following surgical treatment of bronchiectasis is presented and followed by a brief account of the complications which were encountered. It goes without saying, however, that many factors must be taken into consideration in an exhaustive critical evaluation of the frequency and importance of such complications. In addition to operative and anaesthetic techniques, pre- and postoperative antibacterial treatment as well as physiotherapy play an important part in the prevention of postoperative complications; the proper selection of suitable subjects for operation is also of great importance. In the final evaluation of surgery it is important to remember that the function of the lung cannot be assessed on the basis of the chest roentgenograms alone. In bronchospirometric studies, PINNER et coll. showed that pronounced pleural changes often cause more considerable functional damage than advanced parenchymatous disease. In an exhaustive evaluation of the postoperative results of surgical treatment of bronchiectasis the clinical examination must be supplemented by bronchography, bronchospirometry, and studies of the function of the lung both before and after the operation.

SUMMARY

Based on postoperative roentgenographic studies of 103 cases of bronchiectasis, a survey is given of the normal appearance of and changes in the chest following lobectomy or pneumonectomy for bronchiectasis.

ZUSAMMENFASSUNG

Nach postoperativen röntgenologischen Studien in 103 Fällen mit Bronchiektasien wird ein Überblick über das normale Aussehen des Brustkorbes und der Lungen sowie der nach einer Lobektomie oder einer Pulmektomie wegen Bronchiektasien auftretenden Veränderungen derselben gegeben.

RÉSUMÉ

L'auteur, se basant sur l'étude radiographique post-opératoire de 103 cas de bronchectasies, donne un tableau des aspects normaux et des modifications thoraciques après lobectomie ou pneumonectomie pour bronchectasies.

REFERENCES

D'Abreu, A. L.: A Practice of Thoracic Surgery. Edward Arnold, London 1953.

Chesterman, J. T.: Results of Surgery for Bronchiectasis. Brit. J. Surg. 39 (1951—52), 263.

Gombert, H. J., Laux, H., and Winguth, H.: Röntgenologische und klinische Gesichtspunkte bei Lungenresektionen. Fortschr. Röntgenstr. 79 (1953), 157.

Pinner, M., Leiner, G. and Zavod, W. A.: Bronchospirography. J. Thoracic Surg. 11 (1942), 241.

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INTRA-OSSEOUS VENOGRAPHY

In Skeletal and Soft Tissue Abnormalities

by

Franz P. Lessmann, Robert Schobinger von Schowingen, and *Elliott C. Lasser*

In more recent years, radiologists have become increasingly aware of the importance of visualization of the vessels in and about a pathologic process. Concomitant with this realization have been the development and standardization of various techniques for performing these arteriographic and venographic studies. In this paper we propose to review our clinical experience with intra-osseous venography, the newest of the venographic methods. Specifically, we have attempted in this investigation to 1) demonstrate the involvement of the azygos and hemi-azygos veins in diseases of the chest and mediastinum, 2) study the vertebral plexus in normal and pathologic circumstances and 3) determine the feasibility of detecting isolated neoplastic bony involvement earlier than by conventional methods. Our results are based on an evaluation of over eighty intra-osseous injections performed in the Department of Diagnostic Radiology of the Roswell Park Memorial Institute.

Although the anatomy of the venous system appears to be well understood at the present time, some of the physiologic aspects of this system must still be subjected to further investigation. From previous studies it has been shown that substances injected directly into the bone marrow move into the general venous circulation in a relatively sluggish manner. LERICHE and DA COSTA found that the sluggish circulation observed in this region is due to 1) loss of the pulsatory character of the nutrient artery as it passes into the thin bony channels, with consequent decrease in arterial pressure, and 2) the phenomena of dilatation and contraction of intra-osseous vessels.

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In 1943, DRASNER observed that injections and continuous infusions into the bone marrow extending over periods as long as one week did not produce any observable pathologic reactions. Based on this observation, EHRHARDT and KNEIP were the first to suggest the introduction of a contrast medium into the bone marrow. Since this time, JENNY, MALLET-GUY and MICEK, LEGER and FRILEUX and others have carried out a good many interesting clinical investigations based on this principle. In 1950 BAUX, JAMMES, DUCUING, and others studied the venous system of the pelvis using as the site of injection points such as the iliac crest and the ischium, the pubic bones and the greater trochanter. In 1952 FISCHGOLD, ADAMI, ECOIFFIER and PIQUET suggested the injection of contrast into the vertebral spinous process in order to visualize the vertebral venous plexus. These same investigators also injected contrast medium directly into the sternum and into the spinal process of the dorsal spine simultaneously for visualization of the azygos, hemiazygos, intercostal and mediastinal veins. In 1953 TALAIRACH et coll. described the injection of a contrast medium into the occipital protuberance of the skull, in an attempt to demonstrate the anastomosis between the venous circulation of the brain, the meninges, the great sinuses and the vault. TORI studied the azygos and hemiazygos veins by injection of a contrast medium either into the spinal processes or in a particular segment of the anterior or posterior ribs. Most of the investigations described thus far were carried out in normal individuals. More recently, however, MENEGEAUX et coll. studied, by intra-osseous venography, lesions of the bone, such as osteomyelitis and fibrous dysplasia, and SUESSE and AURIG the venous circulation of the chest after intra-osseous venography in carcinoma of the lung.

Before proceeding to a discussion of the present study, some important aspects of the anatomy and circulatory dynamics of the azygos vein and of the vertebral plexus will be reviewed.

Azygos vein. The azygos vein originates in the abdomen and is a continuation of the right ascending lumbar vein. It is about 20 to 25 cm in length and has a diameter of 8 to 12 mm at its junction with the superior vena cava. From its origin in the abdomen, it runs vertically upward passing through a hiatus in the posterior portion of the diaphragm together with the right sympathetic chain. Inside the thorax, it ascends to the right of the aorta and the thoracic duct to the level of the third or fourth dorsal vertebrae where it arches across the right bronchus and enters the superior vena cava. The azygos vein receives 1) the right intercostal veins — the first three or four in a common trunk and the others independently —, 2) the left intercostal veins through the hemi-azygos vein and the accessory hemi-azygos vein, 3) the right posterior

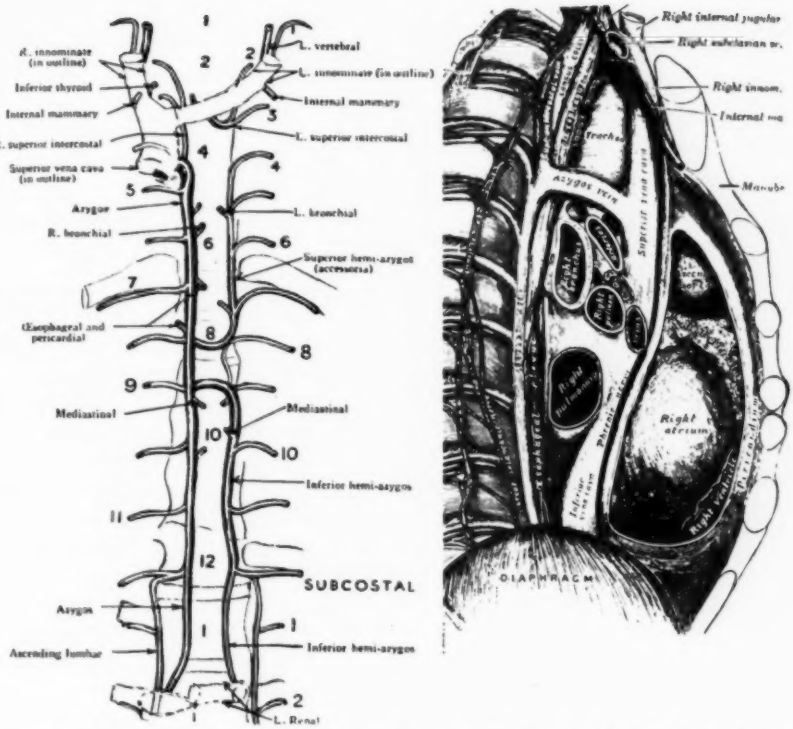

Fig. 1. a. Diagram of the azygos system (GRAY). b. Lateral view of the anatomy of the azygos vein.

bronchial veins and some esophago-tracheal and posterior mediastinal veins (Fig. 1).

The azygos vein is regarded as a bypass and serves as a shunt between the superior and inferior vena cava and forms in a way a great collateral system. The amount of filling of the azygos vein may differ to a certain extent under varying physiologic conditions. Thus, there is greater filling of the azygos system in the supine as compared with the upright position. Likewise, any of the factors that are capable of altering the intrathoracic pressure may affect the degree of filling. Inspiration, expiration, performance of the Valsalva or Müller maneuvers, atelectasis, etc. can, therefore, affect the degree of filling of the vein.

SCHOEN and DAHM have shown in clinical studies that there is congestion of the azygos vein in some cases of bronchogenic carcinoma arising in the right upper lobe. This may also be shown in some instances

Fig. 2. Intra-osseous venography with contrast filling of the azygos vein.

of carcinoma of the esophagus combined with bilateral pleural effusion and dilatation of the three lower-most intercostal veins. Since the azygos vein also drains blood from the bronchial and tracheal veins, bronchial-tracheal varices may develop secondary to constriction of the azygos.

The vertebral venous plexus. The plexus of veins about the vertebral column may be divided into internal and external groups according to their positions, inside or outside of the vertebral canal. The plexuses of these two groups anastomose freely with one another and end in the intervertebral plexus. Both the external and internal vertebral venous plexuses may be further subdivided into anterior and posterior divisions. The anterior external plexus lies in front of the bodies of the vertebrae, communicating with the basivertebral and the intervertebral veins, and receives tributaries from the vertebral bodies. The posterior external plexus surrounds the vertebral spinous processes and communicates anteriorly with the internal vertebral plexuses. The internal vertebral plexuses, which lie within the vertebral canal between the dura mater and the vertebrae and receive tributaries from the bone and from the spinal cord, are divided into anterior and posterior groups according to their position within the canal. They form a closer network than the external vertebral plexuses and run mainly in a vertical direction, forming four longitudinal veins, two in front and two behind the spinal cord.

The blood from the cancellous tissue of the vertebral bodies is collected by the basivertebral veins. These take a radial direction and communicate both with the transverse vessels that connect the longitudinal sinuses with the external vertebral plexus and with the external plexus on the anterior surface of the vertebral body. The intervertebral veins emerge from the longitudinal sinuses at each vertebral level and pass to the intervertebral or anterior sacral foramen. Here they receive numerous tributaries from the external vertebral venous plexus, as previously mentioned. They then connect with the segmental body wall veins of

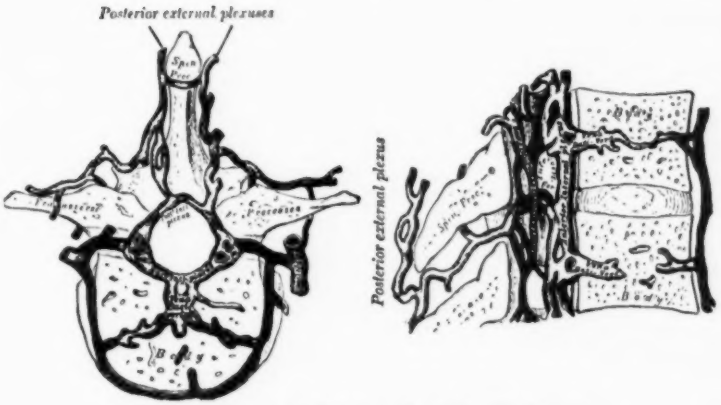

Fig. 3. Anatomy of the vertebral plexus (GRAY).

each region. Thus, in the neck they open into the deep cervical veins: in the chest, into the intercostals; in the abdomen, into the lumbar; in the pelvis, into the sacral veins (Fig. 3).

BATSON in 1940 describes the vertebral plexus system of man as a valveless, plexiform set of veins lying outside of the thoracic-abdominal cavity and not subjected to the direct pressure of the thoracic-abdominal cavities. Included are all the veins of the head and neck, the valveless vessels of the thoracic-abdominal wall and the vasa vasorum. All of these veins have the characteristics of communicating with the intracavitary veins at each segmental level, thereby joining the superior vena cava to the inferior vena cava without intermediation of the lungs. The system is thus the counterpart of the azygos system of veins that lies within the thoracic-abdominal cavity.

It becomes apparent that embolic cells from tumors located within the pelvis may easily gain entrance to this system and thus be transported to the bones of the pelvis, to the lumbar vertebrae, up to the dorsal spine and bones of the thorax and to the skull. It also seems likely that cells from breast and thyroid tumors could enter this system through the intercostal or cervical communications. COMAN has shown by experimental procedures that this theoretical pathway is indeed used. Suspensions of tumour cells injected into the femoral veins of rats and rabbits, while the abdominal pressure was temporarily elevated, were diverted into the vertebral system of veins and produced metastatic tumors in the vertebral bones. In these areas, tumor cell emboli were found to be plugging the ramifications of the vertebral plexus. It is apparent, then, that tumors arising in almost any location may reach the bones of the skeletal axis without passing through either lung or liver filters.

Technique: The procedure, which is relatively simple, is carried out in the following manner. An ordinary bone marrow set with a size 17 bone marrow needle and three syringes of 2 ml, 10 ml and 20 ml size are utilized. Before the study is undertaken, the usual precautions are observed in regard to possible allergy to iodine. The patient is sedated with Seconal about one-half hour prior to the examination and 30 milligrams of Demerol are given intravenously just before the examination. After local anesthesia of the selected site with 1 % procaine has been carried out, the bone marrow needle is introduced down to the periosteum. Then, with additional pressure and in some instances a rotary motion, the needle penetrates into the cortex of the bone and then down to the medullary cavity. When the needle is felt to be securely in place in the medullary cavity, an aspiration is carried out and a small amount of bone marrow aspirate proves that the needle is in a correct position. To insure adequate visualization of the needle, a preliminary film is obtained after the injection of 1 to 2 ml of the contrast medium. Thus far in these studies, 70 % Urokon has been used. The position of the patient on the radiographic table will vary in accordance with the site selected for injection. Although the contrast medium is cleared rapidly from the site of injection, manual exchange of films will allow three to four films to be obtained. In this investigation, an automatic rapid cassette changer has been used principally when visualization of the venous system of the thorax was desired, and sequential inspiratory and expiratory maneuvers were practiced in an attempt to increase the venous flow. In over 80 injections carried out thus far, in this Institute, no untoward incident has occurred. In some instances, the patients complain of a feeling of compression at the site of injection but to date there has been no need for utilizing general anesthesia in this procedure. Follow-up films made six to eight hours later showed no residual contrast medium at the site of injection.

Clinical cases. Forty-five cases were studied with over eighty injections into the bone marrow. Also twenty-five post mortem injections were carried out. The clinical examinations were performed on suspicious lesions involving the bony skeleton, lungs or mediastinum. Some examinations were also done on healthy individuals for study of normal anatomy. The pathologic changes of the venous system and its circulation were studied carefully, and some case presentations may illustrate our findings.

Case 1. RPMI No. 81543. A fifty-three-year-old female was examined in August 1954, complaining of a dull, aching pain originating in the region of the left ilium and radiating along the groin down to the medial aspect of the left thigh of two to three months' duration. Four years earlier, the patient had had a partial colonic resection for carcinoma of the colon.

Roentgen examination of the spine showed an osteoblastic lesion involving the body and the neural arch of the 12th dorsal vertebra. Intra-osseous venography was carried out by injection of 20 ml of Urokon 70 % into the spinous process of the 1st lumbar vertebra. Resultant films showed what appeared to be a complete block in the region of both the internal and external vertebral plexus at the level of D12. The adjacent veins of L1 and L2 were distended and tortuous; a collateral system had developed and the contrast medium passed into the inferior vena cava and the lower portion of the hemiazygos vein (Fig. 5). In a normal individual, both the internal and external vertebral plexuses of the injected vertebra and of the vertebrae several levels above the site of injection should be filled with contrast medium. Failure to demonstrate the internal vertebral plexus of D12, in this instance, suggests the presence of a mass within the

Fig. 4. Contrast filling of a normal vertebral plexus after injection into the spinous process of L3.

Fig. 5. Case 1. Injection into spinous process of L1 (↓) in a case with an osteoblastic metastasis in D12 from primary carcinoma of colon. Note block of vertebral plexus above this level and collateral drainage from injection site into inferior vena cava (→).

neural arch of D12, obstructing the normal plexus in this area. Subsequent to this procedure, a myelogram was performed which showed an extra-dural mass at the level of D12. This was confirmed by operation.

Case 2. RPMI No. 81965. Forty-eight-year-old female with a history of squamous cell carcinoma of the cervix for which she had been given a course of external irradiation just prior to her examination in this hospital. The physical examination revealed a Stage II carcinoma of the cervix. On a subsequent examination, the patient complained of some pain in the middle aspect of the right leg, also along the medial aspect of the left leg. Films of the lumbar spine showed a destructive lesion of L4. A lumbar myelogram showed an almost complete block to be present.

For further evaluation, an intra-osseous venogram was performed inserting the needle at the level of L4. The external vertebral plexus was adequately visualized at the L5 and L4 levels, but the corresponding internal vertebral plexus was not demonstrated. Again there appeared to be obstruction of the internal vertebral plexus in the involved area, secondary to extension of a metastatic tumor into this area (Fig. 6).

Case 3. RPMI No. 81195. A thirty-year-old male was seen in this institute for treatment of squamous cell carcinoma of the right tonsillar pillar. Roentgen therapy was given, with good regression of the tumor and of the secondary cervical adenopathy.

Fig. 6. Case 2. Injection into spinous process of L4 in a case with osteolytic metastases from a primary carcinoma of cervix. Obstruction of internal vertebral plexus at level of injection with passage of the contrast medium into ascending lumbar veins (↓).

Shortly thereafter, however, the patient developed a lump overlying the anterior portion of the 5th rib on the right. Examination of this area showed a destructive lesion of the 5th rib to be present, which apparently was metastatic. Previous roentgen examination had shown no abnormality. Intra-osseous venography was carried out by injection of contrast medium into the medullary cavity of the rib in the anterior axillary line (Fig. 7a). The corresponding rib on the left side was injected for comparison (Fig. 7b), and then an obstruction of the anterior intercostal vein on the right side, in comparison with its counter-part on the left side, could be observed. In addition, the dispersion of the contrast medium in the medullary cavity on the right side terminates abruptly at the site of the lesion, in contra-distinction to its dissemination into the comparable region of the medullary cavity on the left side. A collateral or perforant vein crossing the intercostal space above the level of involvement is also visualized on the involved side.

Case 4. RPMI No. 82699. A sixty-six-year-old male had suffered from anterior chest pain and hoarseness for eight weeks prior to his admission. He had lost about 20 kg in weight and had quit his job because of weakness and fatigue. He had had an increasing cough, productive whitish sputum, and, on several occasions hemoptysis. The roentgen examination of the chest, including fluoroscopy and tomography revealed a large mass to be present in the superior mediastinum bilaterally. The intra-osseous venograms at this time revealed a complete block of the azygos vein at the level of D9. The contrast medium was injected into the spinous process of D10. Sputum examinations revealed tumor cells on Papanicolaou's stain and on Papanicolaou's smear. (Fig. 8.)

Patient received a course of irradiation to the chest which he tolerated very well and there was a remarkable decrease in the size of the tumor in the chest.

Case 5. RPMI No. 82472. A forty-one-year-old man was admitted in November 1954. In June, 1954, the patient had begun to cough and develop a fever. He was treated with cough medicine and penicillin for pneumonia. After the fever had subsided, he returned to work but continued to cough, bringing up some sputum which did not contain blood. He had lost about 6 kg in weight. At this time also, roentgen examination of the chest showed findings suspicious of malignancy. He was referred to this institution, and at the time of admission he presented a cough, moderate shortness of breath, weakness, and increased sweating. Large lymph nodes were present in both supraclavicular areas. Roentgen examination of the chest with fluoroscopy and barium swallow revealed a soft tissue density in the region of the superior mediastinum, with marked displacement of the esophagus to the left and anteriorly, by a mass in the mid

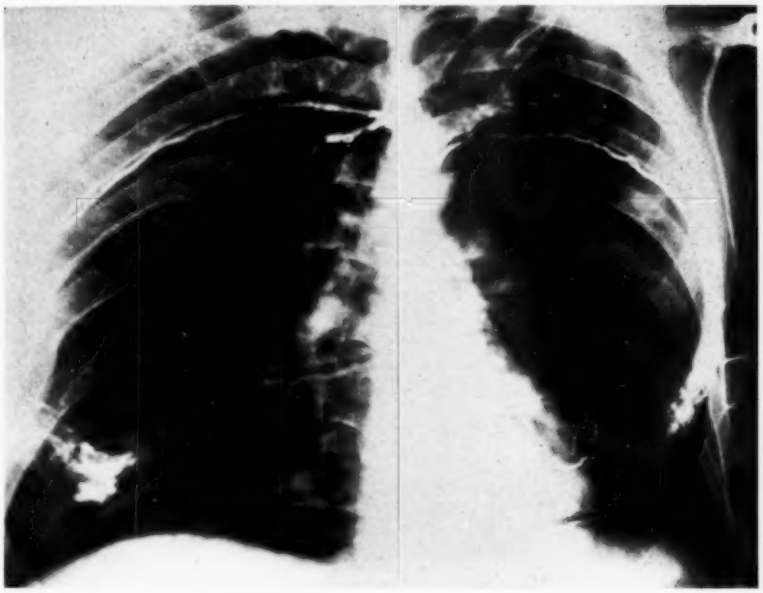

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Fig. 7. Case 3. Metastasis involving anterior end of right 5th rib. (Primary tumor in right tonsil.) a. Injection into medullary cavity of rib just lateral to site of lesion. No contrast medium intra-medullary in the region of the metastasis. No filling of anterior continuation of intercostal veins (cf. normal side). b. Injection into medullary cavity of contralateral rib for comparison.

mediastinum as well as the posterior mediastinum. There was also evidence of enlarged hilar nodes bilaterally, particularly on the left, and left pleural effusion. Intra-osseous venography, with injection of contrast medium in the 9th rib on the right, shows on the p. a. view a complete block of the azygos vein. Here also, the contrast passed down the vertebral plexus to the ascending lumbar veins. An injection was also performed in the 2nd rib on the right, anteriorly, just above the tumor mass, revealing a filling of the internal mammary vein and filling of the azygos at its communication with the superior vena cava, indicating that the azygos block must be somewhere below this level. Visualization of the thoracic lateral plexus including the distal portion of the subclavian vein was also noted (Fig. 9).

Biopsy of the right supraclavicular nodes in November 1954 showed an anaplastic carcinoma. Smears taken during the bronchoscopy from the right main bronchus revealed tumor cells. Patient had a course of irradiation therapy: 5,000 r to the depth of the lesion in the mid superior mediastinum. He improved greatly and there was considerable decrease of the previously described mass in the mediastinum as well as the density in the right upper lobe.

Intra-osseous venography after the treatment showed a recanalization of the azygos vein which was well outlined up to its junction with the superior vena cava.

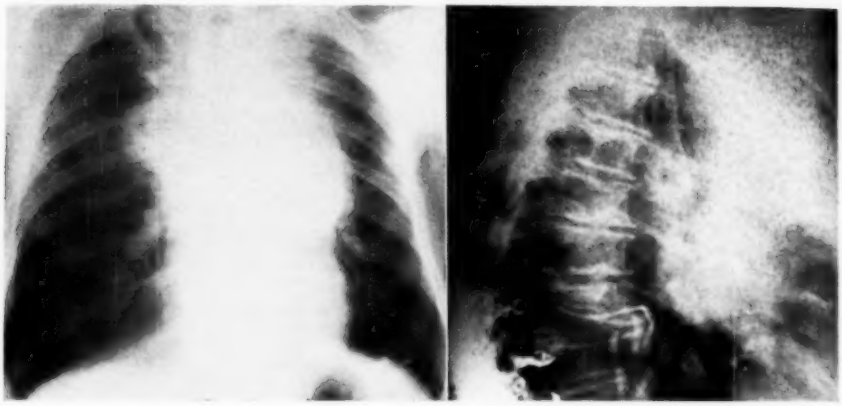

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Fig. 8. Case 4. a. Mediastinal tumor masses bilaterally. b. Spinous process injection of contrast medium at D10 shows an obstructed azygos vein. The contrast has passed downwards in the azygos instead of towards the heart.

Discussion of abnormal cases

In 18 studies of the vertebral plexus, we found 5 complete blocks of the internal vertebral plexus due to metastatic involvement which were confirmed by myelography. One case in this group showed a block of the internal vertebral plexus between L4 and L5 but had a normal myelogram. For this reason, a bone biopsy was performed revealing metastatic involvement of L4. Evidently tumor thrombi had extended into the vessels of the internal plexus. In 4 cases with traumatic lesions of the vertebrae and questionable disc degeneration of the intervertebral space, normal intra-osseous venograms were obtained. One case of a generalized osteosclerotic, metastatic involvement of the spine also showed normal intra-osseous venographic findings.

In 10 studies of the azygos system, twelve injections were carried out. Five of them revealed a complete block of the azygos vein due to involvement by bronchiogenic carcinoma or adenopathy from tumors in the right upper lobe. Two of these cases were restudied after irradiation and recanalization of the azygos vein was noted in connection with considerable regression of the tumor mass. One case had a partial block of the azygos vein in the upper third in a bronchiogenic carcinoma of the right upper lobe. In two cases of bronchiogenic carcinoma of the left upper lobe normal contrast filling of the hemiazygos and azygos vein was obtained. Two cases, a bronchiogenic carcinoma of the right upper

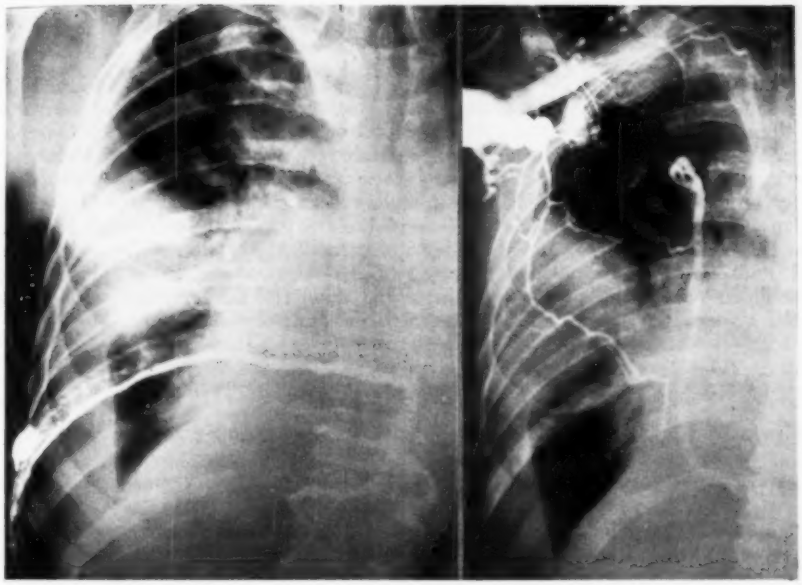

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Fig. 9. Case 5. Bronchiogenic carcinoma of the right upper lobe. a. Contrast injection in the 9th rib shows no filling of the azygos system above this level. b. Injection of contrast in the anterior portion of the 2nd right rib shows that the arch of the azygos is not obstructed. The obstruction lies below the level of the arch and above the level of the 9th rib.

lobe and an esophageal carcinoma, demonstrated a normal azygos vein on p. a. and lateral views.

In 7 thoracic cage studies with osteolytic lesions in the posterior ribs displacement and narrowing of the adjacent intercostal vein occurred. In an anterior metastatic lesion, obstruction to the intramedullary passage of the contrast medium was demonstrated. In two instances with osteoblastic involvement of the ribs, no abnormalities of the intercostal vein were observed. In a coarctation of the aorta with rib-notching, a normal intercostal vein was demonstrated.

The venous system of the pelvic group was demonstrated after simultaneous injection of contrast medium into both iliac bones, as described by LEGER, FISCHGOLD and others. Complete obstruction of the hypogastric veins, with or without displacement of the external iliac veins, and the development of a collateral system could be observed in some tumors of the pelvis. In some osteolytic lesions of the iliac and ischial bones, obstruction of the drainage veins could be demonstrated.

SUMMARY

Malignant neoplasms involving the spinal cord, and possibly the vertebral bodies, may show an obstruction to the passage into the internal vertebral plexus of the contrast medium, which will be diverted below the level of the injection, and the inferior vena cava, the ascending lumbar vein, or azygos at a lower level, will be filled. No abnormalities in cases with disc degeneration or traumatic vertebral involvement have been found. In certain tumors of the mediastinum, and in some groups of primary lung tumors, azygos vein obstruction could be demonstrated. After irradiation treatment, recanalisation has been observed. In malignant bone neoplasms, obstruction of the regional veins and limitation of intramedullary spread of the contrast medium could be demonstrated. In pelvic tumor masses, or osteolytic tumors of the bony pelvis, obstruction of the hypogastric vein, or displacement of the external iliac vein were observed.

ZUSAMMENFASSUNG

Maligne Tumoren, die den Spinalkanal und vielleicht die Wirbelkörper angreifen, können durch Obstruktion die Durchlässigkeit des Kontrastmittels in den Plexus internus der Wirbel verhindern. Dieser wird unterhalb des Injektionsniveaus erweitert sein und die Vena cava inferior, die ascendierenden lumbalen Venen, oder bei tiefer gelegenem Niveau die V. azygos, werden ausgefüllt werden. Keine Abnormitäten sind in Fällen mit Wirbelscheibendegeneration oder mit traumatischen Wirbelschäden gefunden worden. Bei gewissen Mediastinaltumoren und in einigen Gruppen primärer Lungentumoren konnte ein Verschluss der V. azygos demonstriert werden. Im Anschluss an Strahlenbehandlung ist eine Rekanalisation beobachtet worden. Bei malignen Knochentumoren konnte ein Verschluss der regionalen Venen und eine Einschränkung der intramedullären Ausbreitung des Kontrastmittels demonstriert werden. Bei massiven Beckentumoren oder bei osteolytischen Tumoren des knöchernen Beckens wurden Stenosen der V. hypogastrica oder Verdrängungen der V. iliaca externa beobachtet.

RÉSUMÉ

Les tumeurs malignes atteignant la moëlle, et éventuellement les corps vertébraux, peuvent s'opposer au passage dans le plexus vertébral interne du produit de contraste, qui est dévié au-dessous du niveau de l'injection, de sorte que la veine cave inférieure, la veine lombaire ascendante ou l'azygos à un niveau inférieur sont remplies. On n'a pas observé d'anomalies dans les cas de dégénérescence discale ou de lésions vertébrales traumatiques. Dans certaines tumeurs du médiastin et dans certains groupes de tumeurs primitives du poumon on a pu mettre en évidence une obstruction de la veine azygos. Après radiothérapie on a observé sa recanalisation. Dans des néoplasies osseuses malignes on a pu mettre en évidence une obstruction des veines régionales et une limitation de la diffusion intramédullaire du produit de contraste. Dans des cas de masses tumorales pelviennes ou dans des cas de tumeurs ostéolytiques du squelette pelvien on a observé une obstruction de la veine hypogastrique ou un déplacement de la veine iliaque externe.

REFERENCES

Baux, R. and Poulhes, J.: La phlébographie pelvienne. J. radiol. et électr. 31 (1950), 7.

Batson, O.: The function of the vertebral veins and their role in the spread of metastases. Surgery 112 (1940), 38.

— The role of the vertebral veins in metastatic processes. Ann. Int. Med. 16 (1942), 83.

Coman, D. R.: Mechanism responsible for the origin and distribution of blood-borne tumor metastases: a review. Cancer Research 13 (1953), 397.

Dahm, F.: Beiträge zum Röntgen-Bild der Vena Azygos. Fortschr. Röntgenstr. 68 (1943), 268.

Drasnar, V.: Intraspongiöse Dauertropf-Infusion. Schweiz. med. Wchnschr. 76 (1946), 36.

Ducuing, J., Guilhem, P., Baux, R., Enjalbert, A. and Paille, J.: Voies d'injection des phlébographies pelviennes. Soc. d'Electr. Rad. du Sud-Ouest, Bordeaux 1950.

Erhardt, K. and Kneip, P.: Quoted by Tori.

Fischgold, H., Adam, H., Ecoiffier, J. and Piequet, J.: Quoted by Tori.

Jammes, J.: La phlébographie pelvienne par voie pubienne chez la femme. Thèse, Toulouse 1951.

Jenny, F.: Über die Venographie an der untern Extremität, klinische Bedeutung und Technik. Schweiz. med. Wchnschr. 77 (1947), 1195.

Lamas, A., Amados, D. and Celestino Da Costa, J.: A circulãcao do sangue no osso, Amatus. Presse Méd. 54 (1946), 862.

Leger, L. and Frileux, G.: La phlébographie par injection intra-medullo-osseuse du produit de contraste. Presse Méd. 58 (1950), 29.

Leger, L. and Masse, P.: La phlébographie trans-spongio-calcanienne. Presse Méd. 59 (1951), 1560.

Leriche, R.: Physiologie et pathologie du système osseux. Ed. Masson, Paris 1939.

Menegeaux, G., Leger, L. and Détrie, P. H.: La médullographie osseuse. Presse Méd. 61 (1953), 1728.

Mellins, H.: Function of the vertebral venous circulation. Bull. of Univ. Minnesota Hosp. and Minn. Med. Assoc. 22 (1951), 13.

Suesse, H. J. and Aurig, A.: Das transossale Venogramm der Venae intercostales, der Vena azygos und der Vena thoracica interna. Fortschr. Röntgenstr. 81 (1954), 335.

Talairach, J., David, M., Fischgold, H. and Aboulker, J.: Falco-tentoriographie et sinusgraphie basale. Presse méd. 59 (1951), 724.

Tori, G.: The radiological demonstration of the azygos and other thoraco-abdominal veins in the living. Brit. J. Radiol. 27 (1954), 16.

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SACROLUMBAR VENOGRAPHY

by

C. G. Helander and *Å. Lindbom*

Only little attention has been paid to the venous plexuses of the vertebral canal in the medical literature. BATSON (1940) pointed out the existence of these vessels and indicated their possible rôle in the spread of malignant tumours and infection from the pelvis. ANDERSON (1951) showed that these vessels could be contrast-filled in the living subject during compression of the inferior vena cava. FISCHGOLD et coll. (1952) demonstrated the vertebral veins by injections of contrast medium into a spinous process of a lower thoracic vertebra. The diagnostic value of contrast-filling of these vessels has, however, not been investigated. We have worked out a practicable method for the examination of the anatomy of the sacral and lumbar parts of the vertebral venous plexuses and feel it would be of interest to draw attention to these structures.

Method. Following local anaesthesia, polyethylene catheters were introduced into the femoral veins in the groins on both sides in a cranial direction. SELDINGER's method for percutaneous catheterization of vessels was used in all our cases and proved reliable. The tip of the catheter was placed in the iliac vein about 10 centimetres cranial to the site of puncture, *i. e.* approximately at the confluence of the external and internal iliac veins. Saline was then injected continuously or frequently to prevent clotting in the catheter. Catheterization of the veins was not necessary but proved preferable as the patient could be handled more easily and the injection made more safely than with needles, which sometimes slip out. The injections could furthermore be performed at the most suitable site, *i. e.* close to the internal iliac veins.

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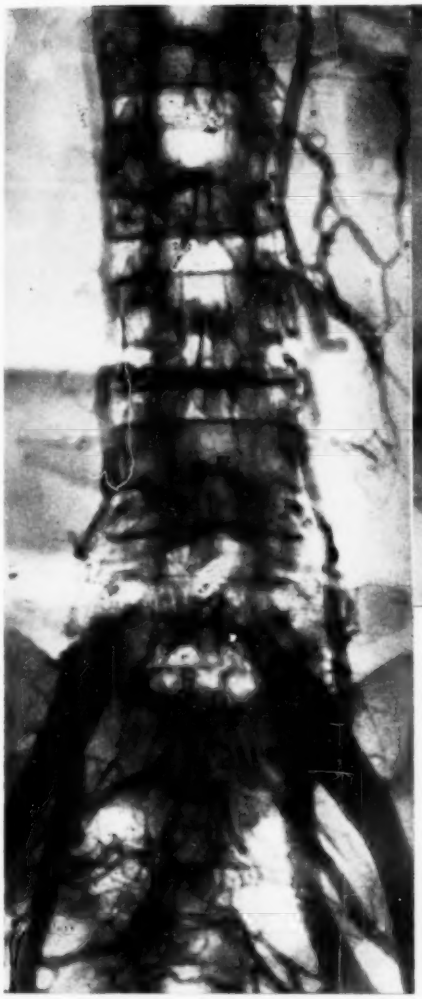

Fig. 1

Fig. 2

Fig. 1. Sacro-lumbar venography. Normal case.

Fig. 2. Oblique projection.

The inferior vena cava was blocked with a football bladder which was pressed against the abdomen with a plastic plate held by a belt. The bladder was placed slightly to the right of the mid-line over the caudal lumbar vertebrae and inflated to a pressure somewhat higher than during urography, thus compressing even the proximal parts of the iliac veins at the sacral promontory (Fig. 3). Thirty (30) ml of a

Fig. 3. Lateral projection. The iliac veins are compressed by the rubber ballon. The venous plexus along the anterior wall of the vertebral canal is visualized.

contrast medium was injected simultaneously into both tubes at a rate of 5 to 10 ml per sec. Umbradil (= diodrast = Perabrodil) 35 % was found suitable. The first film was exposed towards the end of the injection. Three (3) to 4 exposures were made at intervals of 2 to 4 sec with a simple cassette changer moved by hand.

The anteroposterior projection in the supine position was used in all cases (Fig. 1). In some instances an oblique projection with injection solely on the side tilted backwards was found useful (Fig. 2). The true lateral projection was also used (Fig. 3). One patient was examined in both the prone and supine positions. Examinations were furthermore performed on two subjects in both the supine and semi-erect positions with the body tilted backwards and forming an angle of 65° with the horizontal.

No complications occurred in this series.

Material. Seventy-five (75) patients were examined with the method described or slight modifications thereof. The majority of the cases were women between 20 and 60 years of age suffering from cancer of the uterus. The lumbar veins were visualized in like manner and in the main had the same appearance in the women, with and without tumour, and the men examined. We have therefore based our concept of the normal anatomy of the lumbar veins partly on these tumour cases.

In order to study the diagnostic possibilities of the method five cases with expanding processes in the vertebral canal were examined. These cases are described under 'Pathologic findings'. The internal vertebral veins were studied by dissection of five autopsy specimens, three of

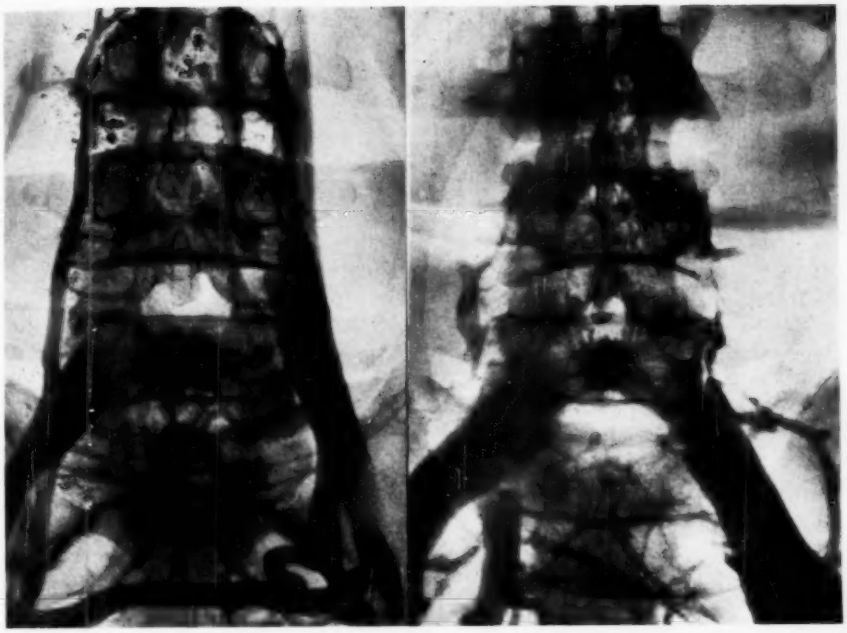

Fig. 4 Fig. 5

Fig. 4. Normal case. Fig. 5. Herniation of the 5th lumbar disc. The venous plexus behind this disc is compressed and not contrast-filled. The veins caudally and cranially to the hernia are visualized (cf. Fig. 4).

which were frozen; blood thus remained in the vessels and facilitated their recognition when the specimen was sliced.

Results. When the inferior vena cava was obstructed, the veins in and around the spine acted as collaterals, transporting the blood from the lower part of the body to the azygos and hemi-azygos veins. When the contrast medium was injected rapidly during occlusion of the inferior vena cava the proximal valves in the femoral veins closed and there was a free passage in a retrograde direction through the internal iliac veins into the presacral vessels. From these the stream passed into the veins in the vertebral canal (Figs. 1 and 4). The contrast medium penetrated into the ascending lumbar veins and other veins along the lateral aspects of the lumbar vertebrae. In the prone and semi-erect positions the veins were visualized in the same manner as in the supine posture.

In three corpulent women no effective compression of the inferior vena cava could be obtained. In all the remaining cases the lumbar veins were visualized.

Anatomic considerations. The loose epidural fibrous tissue in the vertebral canal contains a venous plexus which is situated mainly along its anterior and lateral walls. A rich plexus is present in the cranial part of the sacral canal and along the posterior surface of the body of the 5th lumbar vertebra continuously overbridging the 5th intervertebral lumbar disc along the whole of its posterior surface. At the level of the 4th disc two venous channels — the longitudinal venous sinuses — situated antero-laterally, are formed. Along the posterior surface of each lumbar vertebra there is a plexus formed by the basi-vertebral veins. At the posterior border of the discs there are only the sinuses. In every intervertebral foramen large veins connect the sinuses and the anterior plexus with the ascending lumbar veins and the external vertebral plexuses. Generally, one large vessel could be visualized just under the vertebral arch cranially to the nerve and another vein, sometimes more slender, caudally to the nerve. In the cranial part of the lumbar spine these veins in the intervertebral foramina often had more the character of a plexus. When the veins in the vertebral canal were well visualized these foraminal vessels could always be seen except in a few cases where the corresponding disc was markedly degenerated.

One of the autopsy specimens studied showed advanced disc degeneration. Only small sparse veins could be found in the vicinity of the disc protrusions.

Veins situated in the posterior part of the vertebral canal were never visualized, probably due to their small calibre.

Pathologic findings (five cases). Three patients suffering from lumbar disc herniations with acute sciatica were investigated by this method. Myelography with a water-soluble contrast medium was performed, in all cases visualizing the hernia. Operation confirmed the diagnosis in two cases. In these three cases the venous plexus behind the herniated disc was not contrastfilled as in all the other 72 cases (Fig. 5). The contrast medium remained longer in the pelvic veins than usually and the vertebral veins cranially to the hernia filled but slowly. In one case the hernia was situated laterally. The veins in the corresponding intervertebral foramen did not fill.

Two patients were suffering from Hodgkin's disease. One had signs indicating nerve root pressure corresponding to the 4th lumbar segment. Ordinary films of the lumbar spine showed areas of destruction in the 3rd and 4th lumbar vertebrae. The venograms demonstrated that the venous plexus adjacent to the vertebral destruction was compressed and no veins filled in the cranial part of the corresponding intervertebral foramen (Fig. 6). The other patient had paresis of the urinary bladder. The veins in the right half of the vertebral canal did not fill. After roentgen treatment the signs subsided.

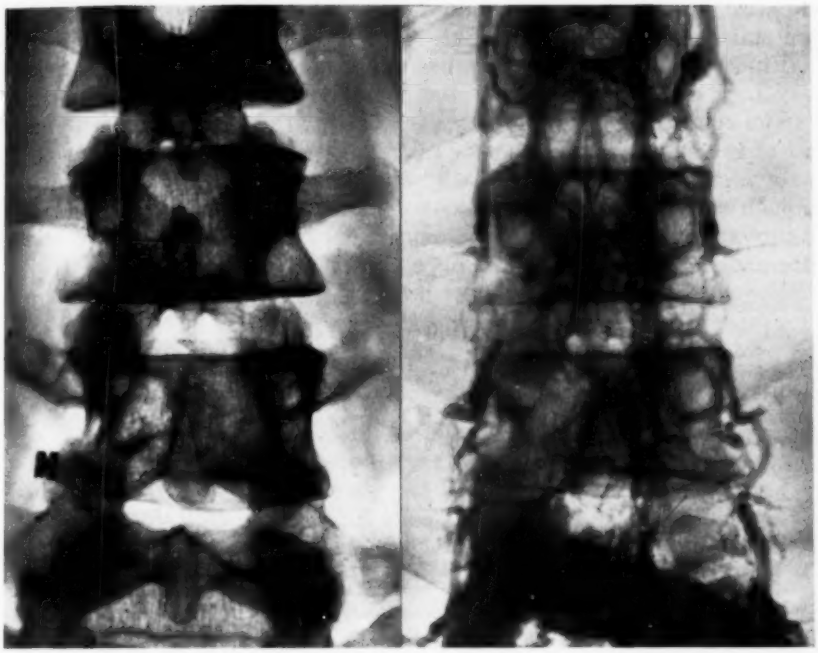

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Fig. 6. Hodgkin's disease with areas of destruction in the 3rd and 4th lumbar vertebrae (a). Venography (b) shows the venous plexus to be compressed adjacent to the destruction in the 4th vertebral body, medially and caudally to the origin of the right pedicle. No veins outlined in the cranial part of the corresponding intervertebral foramen.

Discussion

In some cases a partial contrast-filling of the vertebral veins was seen when no compression of the caval vein was applied but the patient was heavily straining (Valsalva's experiment). This indicates that blood which under ordinary conditions passes up through the vena cava may be forced up through the vertebral veins in special physiologic circumstances. We do not, however, claim that our method is in any way physiologic. We have mainly considered its anatomic aspects. The vertebral veins have thin walls and are situated close to bone or fibrous tissue. They are therefore sensitive to pressure, especially when dilated, and it should be possible to localize expanding processes in the vertebral canal and the intervertebral foramina by this method *e. g.* malignant lymphoma

and disc protrusions. Our limited experience supports the validity of this statement.

Epidural varices which have been described by EPSTEIN and by GLOOR et coll., inter alios, may be visualized with sacrolumbar venography.

The epidural space may be investigated with this method. The caudal end of the subarachnoidal space may be situated at different levels and in some cases even as far cranially as the region of the 5th lumbar disc. In such cases myelography cannot demonstrate whether disc herniation or this anatomic variation is present. Venography may then be used to differentiate between these two conditions.

SUMMARY

A method of examining the sacral and lumbar parts of the internal vertebral venous plexuses is described. The normal venographic appearances of these vessels based upon a material of 70 cases are briefly outlined. The possibilities of the method are discussed and its uses indicated by selected pathologic cases.

ZUSAMMENFASSUNG

Eine Methode zur Untersuchung der sakralen und lumbalen Abschnitte des inneren venösen Wirbelplexus wird beschrieben. Das normale venographische Aussehen dieser Gefässe wird nach den Erfahrungen aus einem Material von 70 Fällen kurz beschrieben. Die Möglichkeiten der Methode werden besprochen und ihre Nützlichkeit wird durch ausgewählte pathologische Fälle aufgezeigt.

RÉSUMÉ

Les auteurs présentent une méthode d'examen des parties sacrée et lombaire du plexus veineux vertébral interne. Se basant sur un matériel de 70 cas ils décrivent brièvement les aspects phlébographiques normaux de ces vaisseaux. Ils discutent les possibilités de cette méthode et posent les indications de son emploi d'après des cas pathologiques sélectionnés.

REFERENCES

ANDERSON, R. K.: Diodrast studies of the vertebral and cranial venous systems. J. Neurosurg. 8 (1951), 411.

BATSON, O. V.: The function of the vertebral veins and their rôle in the spread of metastases. Ann. Surg. 112 (1940), 138.

EPSTEIN, B. S.: Low back pain associated with varices of the epidural veins simulating herniation of the nucleus pulposus. Am. J. Roentgenol. 57 (1947), 736.

FISCHGOLD, H., ADAM, H., ECOIFFIER, J., & PIEQUET, J.: Opacification des plexus rachidiens et des veines azygos par voie osseuse. J. de radiol. et d'électrol. 33 (1952), 37.

GLOOR, P., WORINGER, E., SCHNEIDER, J., & BROGLY, G.: Lombosciatiques par anomalies vasculaires épidurales. Contribution à l'étude de la pathologie du plexus veineux intra-rachidien. Schweiz. med. Wchnschr. 82 (1952), 537.

SELDINGER, S. I.: Catheter replacement of the needle in percutaneous arteriography. A new technique. Acta radiol. 39 (1953), 368.

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MALIGNANT MELANOMA

by

Bertel Jørgsholm and *Inger Engdahl*

Malignant melanomas, of all accessible malignant tumours within the range of therapy, are justly dreaded, not only because of their unpredictable and often extremely rapid course, but by reason of the diagnostic problems, clinical and biological, as well as histological, which make it difficult to institute correct treatment in time.

In Denmark about 50 cases occur annually. A clinical series from the Radium Centre, Copenhagen, will be analysed below, together with a discussion of some of the diagnostic and therapeutic problems.

Material

During the period 1931—1949 a total of 231 cases, diagnosed as malignant melanoma of the skin, have been treated or followed. This does not include melanomas of the mucous membranes, eye, or central nervous system. After re-examination of the microscopic preparations, 10 cases were excluded, as the diagnosis could not be maintained. Another 2 patients were excluded, as they went abroad immediately after the first examination. This leaves 219 patients, 141 females and 78 males, *i. e.* a considerable female preponderance.

The age distribution is set out in Diagram 1, which shows a rather abrupt postpubertal increase in both sexes, whereas the majority of cases had occurred at the usual cancer age. The youngest patient was a 3-year-old girl who succumbed and the oldest a man, aged 94. There is no prepubertal case among the males.

The patients were staged according to their clinical condition when admitted to, or when first seen, at the Radium Centre, *i. e.* Stage I:

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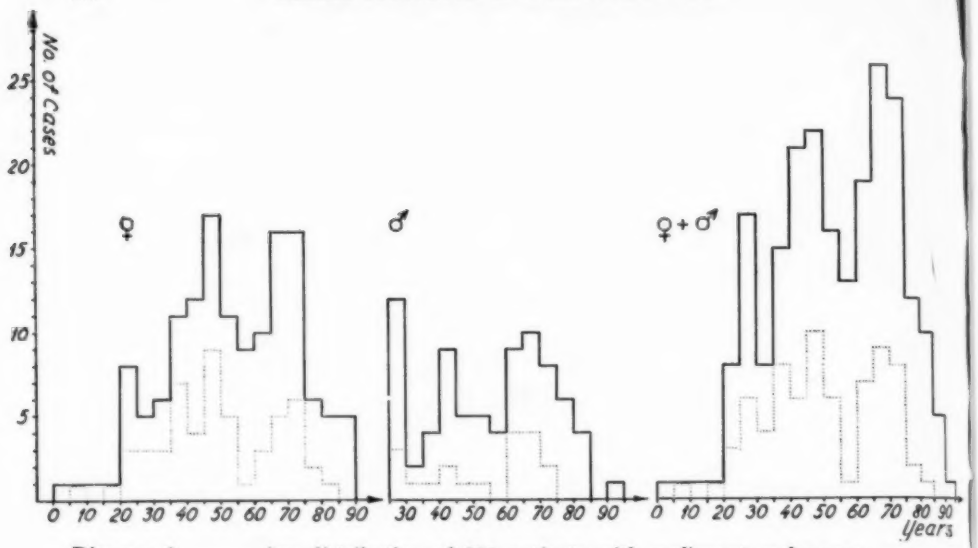

Diagram 1. ——— Age distribution of 219 patients with malignant melanoma; ..... 5-year survivals.

Localized tumour or local recurrence of tumour without demonstrable lymph node involvement; Stage II: Localized tumour and a few enlarged nodes in one regional group, clinically operable; Stage III: Involvement of several lymph node groups and/or distant metastases.

Table 1 gives the staging for both sexes separately and together.

Table 1

Number of patients according to stage and sex

Stage	♀	♂	♀ + ♂
I	90	43	133 (61 %)
II	28	19	47 (21 %)
III	23	16	39 (18 %)
Total	141	78	219 (100 %)

Microscopic verification of the diagnosis was available in 201 cases, or 91.8 %. Out of the 18 cases not confirmed microscopically, 12 had, or later developed, lymph node metastases and succumbed. The remaining 6 were clinically evident cases. Three of them received radium or roentgen therapy without biopsy; three had been treated surgically and, for some reason or other, the operative specimens were not examined histologically, but two of them recurred and received roentgen treatment.

As far as can be deduced, preformed naevi had been present in 92 cases, or in 42 %. Fourteen had melanomas without visible pigmentation.

Previous trauma was reported by 62 patients, or 27.8 %, varying from motor accidents to prolonged irritation by corset steels, garters, and shoes. Quite often the patients admitted that they had picked, pricked, or squeezed the affection. Others had tried corrosives, such as nitric acid or glacial acetic acid. Furthermore, 40 patients had been traumatized by inadequate treatment, such as incomplete excision, electropuncture, or freezing with carbon dioxide, before being referred to us for recurrence, or metastases.

Table 2 shows the location of the primary growth.

Table 2

Situation of primary tumour according to sex

Situation	♀		♂		♀ + ♂	
Head and neck		40 (28.4 %)		26 (33.3 %)		66 (30.1 %)
Trunk		31 (22 %)		20 (25.6 %)		51 (23.3 %)
Upper extremity		13 (9.2 %)		7 (9.0 %)		20 (9.1 %)
Palm	3		0		3	
Subungual	0		1		1	
Lower extremity		46 (32.6 %)		22 (28.2 %)		68 (31.1 %)
Sole	19 (13.5 %)		5 (6.2 %)		24 (11 %)	
Subungual	1		0		1	
Genitalia		9 (6.4 %)		2 (2.6 %)		11 (5.1 %)
Undetermined		2		1		3
Total		141		78		219

As in other series, there is a relative predominance of melanomas on the head, neck, and soles of the feet, in relation to the proportion of these regions of the entire body surface and in relation to the distribution of preformed naevi.

Our therapeutic methods have changed a good deal in the course of time. During the early years of the period under review, radium and roentgen rays were used more than during the latter years in which the main principle has been primary surgical excision, sometimes combined with, or followed by, dissection of the lymph nodes. Since, however, when first seen in the Radium Centre, many patients are inoperable with recurrences, or metastases after previous treatment elsewhere, radium and roentgen irradiation is still used as a palliative measure, and in certain cases in an attempt to obtain cure. The results for the total cases, all forms of treatment considered together, will be seen from Table 3.

Table 3

Five-year end results according to situation

Situation	Total	Dead of other causes without recurrence	Dead of or with melanoma	Living with recurrent melanoma	Living free of symptoms	%
Head and neck	66	9	32	2	23	34.8
Trunk	51	2	39	3	7	13.7
Upper extremity (not incl. palm and subungual)	16	0	11	1	4	25.0
Palm	3	0	1	0	2	
Subungual	1	0	1	0	0	0
Lower extremity (not incl. sole and subungual)	43	0	20	1	22	51.2
Sole	24	2	16	2	4	16.7
Subungual	1	0	1	0	0	0
Genitalia	11	1	8	1	1	9.1
Undetermined	3	0	3	0	0	0
Total cases	219	14	132	10	63	28.8

This table includes also 25 cases too advanced for any treatment or who *solaminis causa* had palliative roentgen irradiation with low doses.

It is evident that the results are best for tumours of the lower limbs, head, and neck. This corresponds quite well to the findings reported from previous and larger series.

Table 4

1931—1949

Five-year results in relation to stage and sex

Stage		Total	Dead of other causes without recurrence	Dead of or with melanoma	Living with recurrent melanoma	Living free of symptoms	%	Previously treated elsewhere	
♀	I	90	7	32	5	46	51.1	24	living 14
	II	28	1	23	1	3	11.1	10	» 1
	III	23	0	23	0	0	0	17	» 0
	I—III	141	8	78	6	49	34.0	51	» 15
♂	I	43	6	22	3	12	27.1	11	living 5
	II	19	0	16	1	2	10.5	9	» 0
	III	16	0	16	0	0	0	11	» 0
	I—III	78	6	54	4	14	17.9	31	» 5
♀ + ♂	I	133	13	54	8	58	43.6	35	living 19
	II	47	1	39	2	5	10.6	19	» 1
	III	39	0	39	0	0	0	28	» 0
	I—III	219	14	132	10	63	28.8	82	» 20

Table 4 shows the 5-year results in relation to stage and sex and the number of cases previously treated elsewhere. As apparent from this table, the prognosis in Stage I is for melanoma, as for other forms of cancer, distinctly better for the females. This applies to all locations, but particularly to tumours of the head and neck.

To obtain a basis for comparison with other series, the material was divided according to McDonald and Sylvén into a determinate group and an indeterminate group.

Table 5

Tabulation of main results

Total number of patients presenting themselves for treatment	219
Total number of patients treated	194
Indeterminate group	
Dead within 5 years of other causes without melanoma	14
Untraced	0
Total number of indeterminate cases	14
Determinate group	
Total number	180

	Conventional 5-year results	End results April 1954
Failures		
Dead of or with melanoma	107	116
Living with recurrent melanoma	10	3
Total number of therapeutic failures	117	119
Successful results		
Free of melanoma	63	61
Prepubertal group (3) living	1	1
Adult group, living free of melanoma	50	48
Adult group, dead of other causes but free of symptoms more than five years after treatment	12	12
Conventional net five-year end-result	35.0 %	
End results as at April 1954	33.9 %	
Over-all end results including all patients as at April 1954	27.9 %	

This grouping shows that only 2 of the 5-year cures developed recurrences or metastases at a later date, *viz.* 6½ and 10 years after treatment. Another 12 of the 5-year cures later succumbed to other diseases without signs of recurrences or metastases.

As already mentioned, the methods of treatment varied in the course of time. In the early years the most common methods were radiotherapy alone or combined with surgery. Moreover, a number of patients had previously been treated elsewhere and not been referred to the Radium Centre for radiotherapy until recurrences or metastases appeared.

Table 6

Treatment of 133 patients with malignant melanoma stage I according to situation. Patients and (in brackets) patients living free of symptoms after 5 years

	Head and neck	Trunk	Upper extrem.	Palm	Lower extrem.	Sole + sub-ungual	Genitalia	Total
Excision	19 (8)	11 (3)	2 (2)	1 (1)	12 (10)	5 (2)	2 (0)	52 (26)
Excision followed by lymph node dissection	5 (2)	8 (1)			4 (3)	4 (1)	1 (0)	22 (7)
Excision followed by lymph node dissection and roentgen therapy	1 (1)	3 (0)	1 (0)		2 (0)	2 (0)		9 (1)
Excision and roentgen therapy	7 (2)				7 (4)	1 (0)		19 (8)
Radium only	8 (5)							8 (5)
Roentgen therapy only	4 (2)				3 (2)			7 (4)
Radium or roentgen therapy followed by lymph node dissection	3 (0)			1 (0)				4 (0)
Radium or roentgen therapy followed by excision	3 (2)	1 (0)	1 (0)	1 (1)	1 (1)			7 (4)
Radium or roentgen therapy followed by excision and lymph node dissection	1 (1)	1 (0)	2 (2)			1 (0)		5 (3)
Total	51 (23)	28 (6)	6 (4)	3 (2)	29 (20)	13 (3)	3 (0)	133 (58)

Table 6 shows the results for Stage I according to the different therapeutic methods. What is most striking is the relatively favourable results of pure radiotherapy, 9 out of 15 Stage I patients being symptom-free at the end of 5 years. Out of these 9 cases, 6 were confirmed histologically. Another 2 patients with local recurrence following previous surgery were cured by radiation.

The prognostic outlook in the presence of regional metastases is a matter of great interest. Table 7, therefore, gives the results of the different therapeutic methods for the Stage II cases and those Stage I cases which subsequently developed regional metastases, whereas the patients who also had distant metastases are ruled out. As evident from the table, 9 out of 86 patients were saved by lymph node dissection, in two instances combined with postoperative roentgen irradiation to which, however, too much importance should probably not be attached. Radiotherapy alone of the lymph node metastases could not save any of the 16 patients thus treated. The situation of the primary growth in the 9 surviving patients was as follows: Lower extremities in 4 (right foot, right thigh, left leg), head in 2 (behind left ear and in the right parietal region), right upper arm in 1, right chest in 1, and clitoris in 1.

Out of the 5 survivors of the first group (Stage II patients), 3 had the lymph node dissection in the same stage as the excision of the pri-

Table 7

Treatment of 47 patients with malignant melanoma and regional lymph node metastases (stage II) when first seen, and 35 patients (stage I) developing regional lymph node metastases after the first treatment

	Stage II cases when first seen		Stage I cases when first seen		Total	
	Patients	5-year cures	Patients	5-year cures	Number	Cures
Excision	3	0			3	0
Excision followed by lymph node dissection	14	4	11	1	25	5
Excision followed by lymph node dissection and roentgen therapy	7	1	9	1	16	2
Excision and roentgen irradiation of lymph nodes	7	0	9	0	16	0
Radium or roentgen therapy only	7	0			7	0
Radium or roentgen therapy followed by lymph node dissection	4	0	4	0	8	0
Radium or roentgen therapy followed by excision and lymph node dissection	2	0	4	2	6	2
Palliative roentgen irradiation or no treatment	3	0	2	0	5	0
Total	47	5	39	4	86	9

mary growth. In the remaining 2, the dissection was performed 4 and 7 months, respectively, after the removal of the primary.

As for the 4 survivors in the second group (*i. e.* in Stage I when first seen) the operation was carried out when the nodal involvement was discovered 4 months to 7 years after the removal of the primary (4 months, 1 year, 6 years, and 7 years, respectively).

In 3 (axillary, crural, and occipital involvement) of the 9 survivors, the operation consisted merely in local lymph node extirpation (in one case, however, followed by radical lymph node dissection one year later, when a new node was detected). The others had radical regional lymph node dissection, in 2 instances combined with unilateral dissection of the iliac nodes although no metastases had been found there. Microscopic examination showed metastases to one node, without capsular perforation in 7 cases, and involvement of several nodes in 2 cases. In one of these cases, a woman with a clitoral melanoma and large inguinal nodes on both sides, there was capsular perforation and invasion of the surrounding adipose and muscular tissue. (In this instance, radical bilateral dissection of the inguinal nodes was performed, whereas the pelvic nodes were not removed.)

Prophylactic lymph node dissection was carried out in 10 cases of Stage I, 5 females and 5 males, and no microscopic involvement was found. All the females are symptom-free at the end of 5 years, whereas all the males have succumbed to metastases, except for one patient who is alive with metastases.

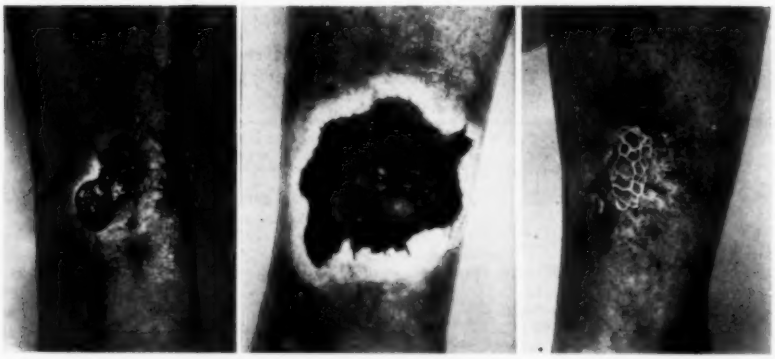

Fig. 1. Case 1. Left: before treatment; middle: 5 weeks after treatment; right: 6 years after treatment.

The results to be obtained by radiotherapy are naturally of great interest. Table 7 showed that the results of pure radiotherapy in malignant melanomas Stage I are surprisingly good, with a reservation necessitated by the small numbers involved. Nine out of 15 patients treated with irradiation only, and 2 irradiated for local recurrences after surgical treatment, are symptom-free at the end of 5 years. These results are illustrated by the three case histories below.

Case 1 (46626). Male, aged 75, who for 10 years, during periods after repeated injury, had had an ulcer on the left lower leg. Shortly before he was seen in 1947, the affection had become dark and nodular. When he presented himself at the Radium Centre he had an elevated, bluish-red to bluish-black, vulnerable, typical melanoma measuring 4 × 2 cm on the left lower leg. No palpable lymph nodes. Biopsy showed malignant melanoma.

Since operation with plastic cover was out of the question, amputation was the only possible course. Considering the patient's advanced age, it was decided to employ roentgen irradiation through two tangential fields; he was treated as an out-patient. The treatment induced oedema and only slight subsidence of the tumour. The patient was then admitted and treated during the subsequent period with heavy fractionated roentgen contact therapy distributed on 2 small central fields and 8 small marginal fields around the elevated part of the tumour. A total of 2,400 r was delivered to the 2 tangential fields in 9 days, and after an interval of 3 weeks, 6,500 r to the central part in 19 days, as well as 4,250—5,600 r to each of the marginal fields in 19 to 25 days. The tumour now became flattened and exhibited a marked exudative reaction replaced by necrosis which healed slowly in the course of the next 9 months. There is still some pigmentation at the site. The lesion has remained healed, and in April 1954 (7 years after the treatment) there is only slight dry crusting and atrophy of the irradiated skin area with flat, residual pigmentation in the centre. No evidence of oedema; no symptoms. (Fig. 1.)

Case 2 (35478). Female, aged 48, who for many years had had a black naevus on the medial border of the left foot. This had become ulcerated 6 months before she

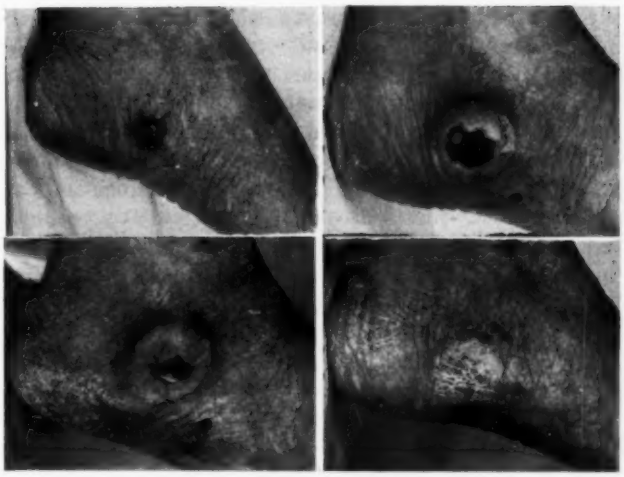

Fig. 2. Case 2. Top left: before treatment; top right: 3 weeks after treatment; bottom left: 4 weeks after treatment; bottom right: 3 months after treatment.

was first seen. An examination revealed a dark pigmented, elevated melanoma, 12 × 12 mm, with a central, achromatic, vulnerable prominence on the medial border of the left foot. No biopsy was performed. Roentgen contact therapy (60 kV 5 cm) was started, 6,000 r/25 days, which resulted in a marked moist reaction healing in the course of 6 weeks. The tumour subsided, while the pigmentation persisted for a long time but eventually disappeared. Symptom-free at the end of 6 years (Fig. 2).

Case 3 (23290). Female, aged 60, who for the past 15 years had had a slowly growing naevus on the right cheek. Recurrences after 2 operations, the last performed one year prior to the first examination at the Radium Centre in 1940. Clinical examination: A brownish-black, elevated, infiltrated naevus, 2 × 2 cm, with central ulceration on the right cheek. No biopsy examination. Roentgen contact therapy 7,300 r/9 days (60 kV 5 cm). The tumour subsided rather quickly, but the pigmentation disappeared slowly. Ten years later breast cancer developed and was treated by operation, but the patient died 18 months later — without a recurrence of the naevus.

Discussion

Malignant melanoma is generally taken to mean a proliferating, more or less pigmented naevus with a marked tendency to form metastases. It originates in a pigmented mole or in apparently normal skin or mucosa. (Histologically, it is made up of more or less poorly differentiated, polymorphous melanoblasts with or without pigment, showing invasion of the surrounding structures, and usually round cell infiltration.)

What is the pathogenesis of malignant melanoma? Opinions have been divided, but it is a fact that about 50 % arise in preformed naevi,

particularly those which have been exposed to chronic irritation, *int. al.* because of their situation. Other melanomas originate *de novo* in apparently normal, smooth skin without any pre-existing naevi. It must be borne in mind, however, that a naevus may well be so minute as to be invisible to the naked eye. In no small number of cases with widespread metastases the primary growth has not been found or at least not until a careful search had been made. The pathogenetic significance of trauma is a disputed question, and it is difficult to procure any final proof as it can seldom be known whether the naevus had become activated prior to injury. It is the general impression and widely accepted, however, that any inadequate manipulation or treatment of naevi, which form the origin of malignant melanomas, may induce their malignant transformation and thus prove fateful. The significance of this observation is partially veiled by the frequently long latent period before malignancy becomes manifest, a fact known to be true for other kinds of cancer. While an unmistakable relationship appears to exist between chronic trauma and the development of malignancy, the relationship to a single injury is more doubtful, as the time of transition to malignancy can practically never be decided.

It is not every form of naevus that seems to be able to undergo malignant change. Thus, soft brown hairy moles and small brown flat blemishes must be considered innocent in every respect. The slightly raised, more or less pigmented, moles with a smooth surface, on the other hand, involve a certain, though usually slight, risk of malignant transformation.

Owing to their varying appearance and pigmentation, preformed naevi are difficult to classify clinically, but it is easier to set up well-defined histologic types, *viz.* 1) intradermal naevus (the ordinary soft brown mole in adults), 2) junctional naevus, 3) compound naevus, 4) juvenile melanoma, and 5) blue (JADASSOHN-TIECHE) naevus.

Recent histologic studies by ALLEN and SPITZ appear to show that all malignant melanomas, apart from the rare malignant blue naevi, arise in the so-called junctional or compound naevi, *i. e.* naevi where the melanoblasts are wholly or partially situated within the epidermis. On the other hand intradermal naevi, whose naevus cells are situated beneath an intact epidermis, never undergo malignant transformation. This also affords an explanation of the relative frequency of malignant melanomas on the soles, fingers, toes, and genitals, compared with the distribution of naevi in other sites. The fact is that naevi in the former sites are almost invariably of the junctional type, whereas only 12 % of the ordinary naevi in adults contain a junctional component.

In children, on the other hand, a junctional component is present in about 98 % of intradermal naevi. During and immediately after

puberty, an alteration as regards purely intradermal naevi takes place. This process gradually takes the form of a kind of involution, and at the same time new naevi arise or become visible. This introduces another factor in the development of melanoma, the endocrine factor. It is well known that a fatal malignant melanoma is extremely rare before puberty, that a relatively abrupt increase takes place during the post-pubertal years, and that the majority occur at the usual cancer age. Furthermore, a malignant melanoma occurring during pregnancy seems to be invariably fatal. When it is realized that the administration of ACTH and cortisone may induce junctional naevi, the relationship between the pathogenesis of melanomas and the endocrine system does not appear unlikely. But just as in the case of other malignant tumours subject to endocrine influence, such as mammary and prostatic carcinomas, the exact mechanism is still unknown. No definite connections with given endocrine factors have yet been found although the elucidation may perhaps not be so far off.

With a few exceptions malignant melanoma belongs to external, accessible cancers and yet it is often difficult and sometimes impossible to make the diagnosis sufficiently early. There are several reasons for this.

In the first place, any human adult has on an average 20 visible naevi in addition to those which cannot be seen. Which of these may undergo malignant change it is impossible to tell before the activation has started and some sign or other has become manifest. Since, however, the development of melanoma is sometimes preceded by a precancerous stage or by activation of a naevus consisting in growth, elevation, increased pigmentation, ulceration and bleeding, as well as slight subjective symptoms, there is a possibility of early diagnosis — unfortunately often neglected.

Another factor, which makes the early diagnosis difficult, is the tendency of the melanoma to the early and widespread formation of metastases via the lymph or blood, at times in combination with an invisible or almost invisible primary tumour. This is presumably related to the lack of cohesion of the melanoblasts compared with other cells, their architecture of dendritic processes providing them with the power of independent motion and penetration, and capacity to divide and develop isolated in any medium in the organism.

A third difficulty is the clinical diagnosis of a manifest malignant melanoma. This naturally does not apply to typical, pigmented, infiltrating, raised, and vulnerable melanomas, but to the achromatic varieties and the slowly proliferating, often innocent-looking, flat or papillomatous naevi which, due to diagnostic errors, are not infrequently subjected to inadequate treatment. In such cases, however, even an experienced

clinician may be mistaken, and it is difficult to set up definite clinical diagnostic criteria before metastases have been formed. At our present stage of knowledge, any naevus showing signs of proliferation, *i. e.* growth in circumference or height, ulceration, bleeding, or increased pigmentation should be considered a potentially malignant tumour and be treated as such.

Histologic diagnosis of malignant melanoma involves two difficulties: in the first place the difficulty of obtaining a biopsy specimen for microscopic examination, before treatment is instituted, and in the second place the difficulty of always making a diagnosis of malignant melanoma with certainty. With the background of the numerous cases of rapid metastasization following inadequate excision, including biopsy, in mind, it must be considered a technical error to remove a biopsy specimen from a melanoma suspected of malignancy. Even biopsy followed by operation in the same stage cannot be said to be devoid of risk, when it is realized that melanoma cells often l e free in the lumina of blood vessels and lymphatics in the vicinity of the tumour and perhaps need only a slight mechanical action or environmental alteration to be carried off into the circulation.

The histologic difficulties of making a definite diagnosis of malignant melanoma are old and still exist. They are due, partly to confusion of the different varieties of naevi in children and adults, which has led to misinterpretations, partly to the cellular polymorphism, and, finally, to the absence of histologic criteria applicable with certainty in deciding whether a specimen represents a true malignant melanoma or a cellular or proliferating naevus of a more innocent nature; let alone other differential diagnostic possibilities, such as pigmented basal-cell cancer, extramammary Paget's disease, and various non-neoplastic skin diseases.

In a recent paper, dealing with these problems in great detail, ALLEN and SPITZ have set up criteria, said to be definite, for the histologic diagnosis of primary, malignant melanoma. As already mentioned, they maintain that all malignant melanomas, apart from the extremely rare malignant blue naevi, are derived from epidermic cells and arise in a naevus with a junctional component. To make a diagnosis of primary malignant melanoma, they therefore demand the presence of junctional changes, *i. e.* islets or nests of melanoblasts located within the epidermis. As another necessary characteristic they mention epithelial hyperplasia over and around the melanoma. Additional criteria are invasion of the subepidermal tissue, nuclear and cellular pleomorphism, and round-cell infiltration. Less constant findings are varying pigmentation and mitotic figures. The use of these criteria ought to obviate diagnostic errors and confusion with other, more benign growths in the skin.

A form of naevus which, as mentioned above, is often mistaken histologically for malignant melanoma is juvenile melanoma, mostly occurring before puberty but also later in life. These are hairless, smooth, raised, purple or reddish-brown naevi. Microscopic examination shows a junctional component, polymorphism, and often round cell infiltration, as well as oedema and telangiectases immediately below the epidermis, isolated aggregates of round or spindle-shaped cells and of mono- or multinuclear giant cells. It is a different matter that juvenile melanomas may later, though very seldom, develop into malignant melanomas. This is not so with blue naevi. These structures, which present themselves as smooth, brown to bluish-black, hairless, slightly elevated, rather firm naevi, are of a different histologic architecture, being made up of compact or loosely arranged spindle-shaped, pigmented cells lying in bundles in the subepidermal tissue and similar to smooth muscle or nerve cells. They are fairly easy to distinguish from other forms of naevi of the compound or intradermal type. In rare cases, blue naevi undergo malignant changes, but in these cases the histologic appearances are also distinguishable from malignant melanoma of junctional origin. They may, however, be confused with spindle-cell-like metastases from malignant melanomas.

As regards therapy, there does not seem to be any doubt that surgical treatment must be the main rule, but radiotherapy is also justified in some cases. Surgical treatment may consist in (1) wide, local excision, or electro-excision, in 3 dimensions, *i. e.* 3 to 4 cm beyond the visible limit of the tumour and downwards to include the fascia, (2) excision of the primary tumour and regional lymph nodes, (3) monobloc excision of the primary tumour and regional lymph nodes in continuity, (4) amputation. The question is the extent of the primary operation. In the presence of clinically demonstrable regional metastases, there is no doubt that radical excision and lymph node dissection should be tried if possible, either in the form of excision and isolated lymph node dissection, or of excision of the primary tumour in continuity with the intervening tissue with the lymphatics and regional nodes. But is it right to recommend and aim at such extensive intervention in cases of primary malignant melanomas without demonstrable metastases or is it justifiable to restrict the treatment, in suitable cases, to wide local excision and then keep the nodal regions under close supervision with a view to subsequent dissection if metastases should appear? In this connection, attention must be given to how great are the risks of latent regional lymph node metastases, and, if great, what improvement in the survival rate may be expected if lymph node dissection is performed. It is difficult to assess the risk of latent regional metastases statistically, but it must be considered to be relatively large. From major statistics (Memorial Hospital) we know that for patients submitted to lymph node dissection and showing positive microscopic findings, the 5-year survival rate is about 14 %. Nearly the same applies to our series, whereas the survival rate for patients showing negative microscopic findings was the same as for patients who had local excision. When also it is realized that malignant melanoma has a pronounced tendency to lymphogenous

as well as haematogenous spread, and does not always form metastases first in the regional nodes which indeed it often misses, it is evident that in the presence of latent or demonstrable metastases, the chances are very poor, even though major lymph node dissections or *en-bloc* operations are performed. Furthermore, the chances do not appear to be essentially reduced by deferring these operations until the nodes become clinically demonstrable. It is difficult to say whether major surgical intervention influences the tendency to generalization, but the possibility cannot be ruled out. It is apparent from the major statistics available that a relatively large proportion of the 5-year cures (about 65 %) have been dealt with satisfactorily by means of local excision provided it has been early and radical enough. This also applies to local recurrences after previous operations.

Much of the information at hand, therefore, speaks in favour of restricting the primary treatment of malignant melanomas without demonstrable metastases to local wide excision and to defer lymph node dissection until metastases become manifest. Of course, regard must be paid to other factors, such as the general condition, age, and obesity, and a certain individual approach is necessary in each case. As a link in the treatment, it is important to aim at an earlier diagnosis and always stress the necessity of microscopic examination of any naevus removed, however innocent-looking, so that adequate therapy may be instituted as soon as possible, should the result of the microscopic examination occasion surprise.

Radiotherapy is considered to-day by many only as an *ultimum refugium*, a malignant melanoma usually being thought to be extremely radioresistant and requiring excessive treatment dosage. This is true in many cases, but at times melanomas and metastases from melanomas may respond to a skin cancer dose, or even less. Our series contains a number of cases of primary melanoma which seem to have been permanently cured by massive irradiation. On the whole, there seem to be marked individual differences in the radiosensitivity of melanomas. We therefore do not believe that radiotherapy is antiquated, but is still justified, for example, in elderly debilitated patients, patients who refuse surgery, and as a palliative treatment of inoperable cases. No proof has been advanced that radiotherapy *per se* should accelerate the formation of metastases.

Palliative surgical interventions, such as hypophysectomy (2 cases in the Radium Centre) and adrenalectomy in generalized cases will not be discussed. In our experience, the palliative results obtained so far are not up to expectations. Incidentally, the same applies to irradiation of the hypophysis, rabies vaccination, and hyperthermic treatment.

Conclusions

As far as we can see, the conclusions to be drawn from experiences to date are as follows. Postpubertal patients in whom the diagnosis has been made with the certainty possible without biopsy, and who do not present demonstrable lymph node metastases, should be treated primarily with wide excision or electrocautery without any cosmetic regard, with a 3 to 4 cm margin of healthy tissue and including the fascia. This procedure can then be followed by plastic covering. By painstaking and frequent follow-up examinations, the lymph node regions must be supervised and dissected at the slightest sign of nodal proliferation. If lymph node metastases are demonstrable primarily, the treatment should be wide excision of the primary tumour and isolated dissection of the lymph nodes in the same stage. *En-bloc* excision and lymph node dissection in continuity does not empirically afford more certainty, except in cases of involvement of lymph nodes adjacent to the tumour. Likewise, major amputations of extremities should be reserved for cases deemed inoperable by the above-mentioned procedures, *e. g.* owing to extensive cutaneous dissemination and/or nodal involvement in several regions. In the case of elderly or debilitated patients or patients who for some reason or other cannot be, or refuse to be, submitted to surgery, radiotherapy involves, in spite of all, possibilities which must not be neglected. When performed under careful supervision, it must be regarded as adequate.

SUMMARY

The authors have analysed a series of 219 patients with malignant melanoma, treated partly by surgery, partly by radiotherapy, and partly by a combination of surgery and radiotherapy. The total 5-year cure rate was 28.8 %. The problems relating to the correct and early diagnosis of malignant melanoma and its treatment are discussed.

ZUSAMMENFASSUNG

Die Verfasser haben eine Serie von 219 Patienten mit malignen Melanomen analysiert, die teils nur chirurgisch, teils nur radiologisch und teils kombiniert chirurgisch-radiologisch behandelt worden sind. Die totale Fünfjahresheilung betrug 28.8 %. Die Probleme bezüglich der korrekten und frühzeitigen Diagnose der malignen Melanome sowie deren Behandlung werden diskutiert.

RÉSUMÉ

Les auteurs ont analysé une série de 219 malades atteints de mélanome malin, traitée en partie chirurgicalement, en partie par la radiothérapie, et en partie par une association de chirurgie et de radiothérapie. Le taux total de guérison de cinq ans était de 28.8 %. Les problèmes relatifs au diagnostic correct et précoce du mélanome malin et à son traitement sont étudiés.

LITERATURE

Ackerman, L. V. and del Regato, J. A.: Malignant melanomas of the skin. *In:* Cancer. Diagnosis, Treatment and Prognosis, p. 184. C. V. Mosby Co., St. Louis 1954.

Allen, A. C.: A reorientation on the histogenesis and clinical significance of cutaneous nevi and melanomas. Cancer 2 (1949), 28.

— and Spitz, S.: Malignant Melanoma. Cancer 6 (1953), 1.

Bonser, G. M.: The pigmented tumours of the skin. *In:* Symposium Malignant Melanoma. Brit. J. Radiol. 19 (1946), 229.

Chaoul, H.: Die Nahbestrahlung, p. 131. Georg Thieme, Leipzig 1944.

Christiansen, J. V.: Melanindannelsen i huden (Danish). Nord. Med. 52 (1954), 1609; Bibl. Læger 146 (1954), 85.

Clarke, J. M.: Malignant melanomata. Austr. N. Z. J. Surgery 22 (1952), 8.

Coffey, R. J. and Berkeley, W. T.: Melanoma. Prepubertal malignant melanoma. J. A. M. A. 147 (1951), 846.

Decker, A. M. and Chamness, J. T.: Melanocarcinoma of the plantar surface of the foot. Surgery 29 (1951), 731.

Ellis, F.: *In:* Symposium Malignant Melanoma. Brit. J. of Radiol. 19 (1946), 231.

Farrell, H. J.: Cutaneous melanomas. Arch. Derm. Syph. 26 (1932), 110.

Frädrich, G. and Poppe, H.: Zur Therapie des Melanoms. Dtsch. med. Wschr. 79 (1954), 1051.

Galgano, A. R.: Long survival in malignant melanoma. J. A. M. A. 152 (1953), 518.

Goldman, L. and Richfield, D. F.: Effect of corticotropin and cortisone on development and progress of pigmented nevi. J. A. M. A. 147 (1951), 941.

Gage, M. and Dawson, W.: Malignant melanoma. Ann. Surg. 133 (1951), 772.

Hamilton, J. B.: Influence of the endocrine status upon pigmentation in man and in mammals. *In:* The Biology of Melanomas. Spec. publ. New York Acad. Sc. 4 (1948), 341.

Hellriegel, W.: Zur Behandlung der malignen Melanome. Strahlentherapie 86 (1952), 548.

Hultberg, S.: Untersuchungen über die Röntgennahbestrahlung. Acta radiol. Suppl. 54 (1943), p. 142.

Khanolkar, V. R.: Pigmented precancerous and cancerous changes in the skin. Cancer Res. 7 (1947), 692.

MacDonald, E. J.: Malignant melanoma in Connecticut. *In:* The Biology of Melanomas. Spec. publ. New York Acad. Sc. 4 (1948), 71.

— Criteria for reporting end results. Am. J. Roentgenol. 60 (1948), 832.

McGovern, V. J.: Melanoblastoma. Med. J. of Australia 1 (1952), 139.

Miescher, G.: Melanom. *In:* Handbuch der Haut- und Geschlechtskrankheiten II, von J. Jadassohn, p. 1046. Springer Verlag, Berlin 1933.

Moir, P. J.: Introductory remarks to discussion on melanoma. *In:* Symposium Malignant Melanoma. Brit. J. Radiol. 19 (1946), 217.

Pack, G. T. and Livingstone, E. M.: The treatment of pigmented nevi and melanomas. *In:* Treatment of Cancer and Allied Diseases. III, p. 2071. Paul Hoeber, Inc., New York 1940.

— Morfit, M. and Scharnagel, I.: The principle of excision and dissection in continuity for primary and metastatic melanoma of the skin. Surg. 17 (1945), 849.

— Perzik, A. L. and Scharnagel, I. M.: Treatment of malignant melanoma. California Med. 66 (1947), 283.

— The management of pigmented nevi and malignant melanomas. South. M. J. 40 (1947), 832.

PACK, G. T. and SCHARNAGEL, I. M.: The prognosis for malignant melanoma in the pregnant women. Cancer 4 (1951), 324.
— GERBER, D. M. and SCHARNAGEL, I. M.: End results in the treatment of malignant melanoma. Ann. Surg. 136 (1952), 905.
— LENSON, N. and GERBER, D. M.: Regional distribution of moles and melanomas. Arch. Surg. 65 (1953), 862.
RAVEN, R. W.: Malignant melanomas and moles. Med. Press 224 (1950), 620.
REITMAN, P. H.: Radiation therapy of malignant melanomas. Am. J. Roentgenol. 67 (1952), 286.
SCHARNAGEL, I. M.: Treatment of malignant melanomas of the skin and vulva at the Radiumhemmet, Stockholm. Acta radiol. 14 (1933), 473.
SYLVÉN, B.: Malignant melanoma of the skin. Acta radiol. 32 (1949), 33.
TOD, M. C.: Radiological treatment of malignant melanoma. *In:* Symposium Malignant Melanoma. Brit. J. Radiol. 19 (1946), 223.
TRUAX, K. F. and PAGE, H. G.: Prepubertal malignant melanom. Ann. Surg. 137 (1953), 255.
WILLIAMS, I. G.: *In:* Symposium Malignant Melanoma. Brit. J. Radiol. 19 (1946), 230.

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FLUORESCENT BADGES FOR USE DURING FLUOROSCOPY

by

D. K. Bewley

This note is intended to draw attention to the value of fluorescent materials for protection during fluoroscopy.

The standard methods of estimating the dosage of stray radiation received by the staff, such as films and pocket ionisation chambers, suffer from the disadvantage that they only give the total amount of radiation received up to the time of measurement; there is no immediate warning when the intensity of the rays reaches a dangerous level. On the other hand a piece of fluorescent screen will do exactly that, if it is carried by a member of the staff during roentgen screening sessions.

We have made up pieces of fluoroscopic screen (Levy-West mark 48) into various forms of badge which can be worn conveniently by the staff; some of these badges are shown in the figure. When they are irradiated by roentgen rays their apparent brightness is greatly dependent upon how well the observer's eyes have become adapted to the darkness, and therefore we have included a patch of self luminous material in the larger badges, to serve as a reference standard of brightness. The self luminous patch is a zinc sulphide phosphor activated with radium at one microgram per square inch, prepared by Brandhurst and Co, of Reading, England. It is almost unaffected by roentgen rays, and after exposure to daylight the afterglow disappears in about a minute. The Levy West screen fluoresces with the same brightness, and with nearly the same colour, as the self luminous patch when the whole badge is irradiated at about 200 mr/hr of scattered roentgen rays generated at 80 kV_p. At greater dose rates the self luminous patch appears as a dark area on a brighter ground. The variation of the sensitivity of fluoroscopic screen has been shown by LORENTZON and WAHLBERG to be only about

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± 20 % over the range 65 to 100 kV_p, for scattered roentgen rays. Some of these badges were made up more than a year ago, and there is no sign of deterioration in most of them.

The self luminous patch is invisible until the observer's eyes have become adapted to darkness, so that the badges serve as a useful criterion of dark adaptation. The latest recommendations of the international Commission on radiological protection include a paragraph emphasizing the importance of sufficient dark adaptation, and these badges should prove useful in deciding whether the working conditions in fluoroscopic rooms are adequate in this respect.

It has also been found that the badges provide a very convenient method of locating leakages of radiation from diagnostic roentgen ray apparatus.

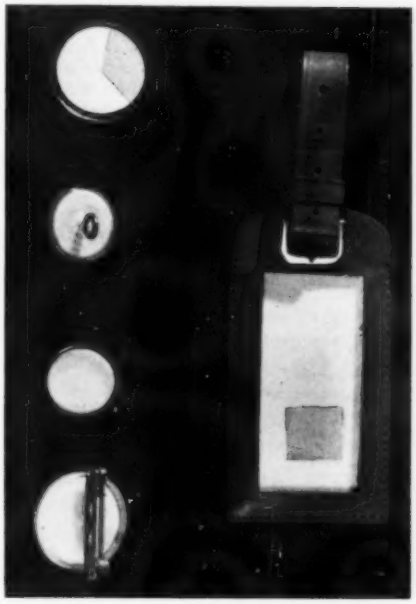

Fig. 1. Various types of fluorescent badge.

A dose rate of 200 mr/hr will deliver a week's maximum permissible dose in about 2 hours. However, the dose rates of scattered roentgen rays, encountered during fluoroscopy, are extremely variable, and if action is taken whenever the luminescence of the badge approaches that of the standard patch, the total dose received during the week will probably not normally be excessive. With brighter screen material the 'standard dose rate' would be reduced if the same self luminous material were used. If a weaker self luminous patch were employed, the comparison of the brightness of the two areas would become more difficult.

An instrument using a fluorescent screen for measuring dose rates has already been described by LORENTZON and WAHLBERG but it is designed for making surveys rather than for use as a personal monitor.

SUMMARY

A method of using a fluorescent screen for the protection of staff during fluoroscopy is described. The inclusion of a radium-activated self-luminous area enables the observer to estimate roentgen ray intensities, and it also enables him to judge the degree to which his eyes have become dark-adapted.

ZUSAMMENFASSUNG

Eine Methode, bei der man einen Fluoreszenzschirm zur Schützung des Personals während der Durchleuchtung benutzt, wird beschrieben. Der Einschluss einer mit Radium aktivierten selbstleuchtenden Zone befähigt den Untersucher, die Röntgenstrahlenintensitäten zu schätzen; sie ermöglicht es ihm auch, den Grad der Dunkeladaption seiner Augen zu beurteilen.

RÉSUMÉ

L'auteur décrit une méthode utilisant un écran fluorescent pour la protection du personnel médical pendant la radioscopie. L'inclusion d'une surface luminescente radiumactivée permet à l'observateur d'estimer les intensités de rayons roentgen et aussi de juger le degré d'adaptation à l'obscurité atteint par ses yeux.

REFERENCE

LORENTZON, L. and WAHLBERG, T.: A simple instrument for radiation protection measurements. Acta radiol. 33 (1950), 305.

BOOK REVIEWS

A STUDY OF THE LOCAL ROENTGEN REACTION ON THE SKIN OF MICE, WITH SPECIAL REFERENCE TO THE VASCULAR EFFECTS. By Finn Devik. With summary and conclusions in Spanish and Russian. 92 pages, 25 illustrations. Acta radiol. Suppl. 119, Stockholm 1955. Sw. Kr. 15: —.

The study was carried out at the Institutt for Generell og Eksperimentell Patologi, Oslo, the Director of which is Professor LEIV KREYBERG. The purpose of the experiments was to investigate the pathogenesis of the tissue reaction to local roentgen irradiation with special reference to the blood vessels. The mechanism of the radiation effects in radiation therapy is still imperfectly understood, and the role of the blood vessels in the response of the tissue is rather uncertain.

In order to cover the general background for the experiments, a short account is given of the theories of the mechanism leading to the radiation cure of a cancer, and a general survey of previous investigations on the effects of radiation on blood vessels is presented.

The acute reaction to a single dose of roentgen irradiation was studied in the skin of a strain of hairless mice. Skin flaps on the back of the mice were irradiated with various doses by means of a Philips Metalix unit. The physical data were: 50 kV, 2 mA, 1 mm Al filter (in some experiments 0 filter), S.F.D. 27 mm, dose rate 677 r/min with 1 mm Al filter. The field irradiated was 1 sq. cm in most animals; in some mice a strip only 1 to 3 mm wide was irradiated. The main dose was 2,700 r which, after a latency period of about 5 days, caused an exudative epidermitis which was most pronounced 8 to 9 days after irradiation, and then gradually receded. The reaction was fundamentally the same as that in the skin in other species, including man. In some mice doses varying from 1,050 to 15,000 r were given.

The observations upon 207 mice are described. The radiation effects on the skin were studied by recording the visible reaction, by investigating histologic sections, by the use of intravascular contrast injections, and by a modified freeze drying technique, designed to visualize the functional and the morphologic state of the blood vessels. A considerable number of the mice were investigated by two or more of the methods. These methods gave information as to the following factors regarding the blood circulation in the irradiated skin: the number, the anatomic distribution and shape of the blood vessels in the whole skin, the rate of circulation, and to some extent the permeability of the blood vessels.

The main results and conclusions are as follows.

The vascular effects are inconspicuous or invisible during most of the latency period.

The initial phase of the acute skin reaction (5 to 7 days after 2,700 r) is accompanied by vasodilation, increased permeation of fluorescein and Evan's blue, and edema; this increase of permeation is considered non-specific, and is, apparently, part of the inflammatory reaction which accompanies the main reaction.

The rate of blood circulation is on the whole increased during the acute reaction, as indicated by observations upon frozen dried preparations. These show that when

the contrast medium has been injected into a tail vein the vessels of the irradiated area become filled with bloodstained by Evan's blue sooner than the non-irradiated blood vessels of the surrounding skin.

Stasis is observed inconsistently and only in small, restricted areas after 2,700 r.

At the peak of the reaction (8 to 12 days after 2,700 r) the calibre of the superficial capillaries increases considerably and erythrodiapedesis occurs. These effects are confined only to the superficial capillaries which lie close to the epithelial cells showing the most pronounced radiation effects in the skin. The capillaries subsequently form large irregular ectasies, and around these numerous effused red blood corpuscles accumulate. The blood circulates in the ectasies. The large ectasies disappear gradually and the capillaries later regain an almost normal appearance. The number seems to be reduced, probably because the ectasies disappear. The capillaries about the radioresistant striated muscle fibres of the subcutaneous skin muscle are affected far less than the superficial capillaries. The muscle capillaries are moderately dilated during the acute skin reaction, but neither ectasies nor erythrodiapedesis is observed, although the dose has been essentially the same in all layers of the exposed skin.

Since a small lag is observed between the morphologic changes in the epithelial cells and the vascular effects at the beginning of the acute skin reaction, the blood circulation being increased rather than decreased during the acute reaction, and since the reaction of the capillaries parallels the radiation effects of the surroundings, the skin reaction seems to develop largely independently of the state of the blood vessels. The vascular changes are therefore considered as being of only secondary importance in the pathogenesis of the acute skin reaction, that is, not caused by direct damage to the endothelial cells by the roentgen rays. The said vascular reactions at this period are regarded as secondary, caused by destruction of epithelial and connective tissue cells, part of an unspecific 'inflammatory reaction'.

As to the skin reaction as a whole, it is considered that the acute phase is mainly dependent on the radiation effects on the epithelial cells.

The first manifest injury due to radiation is the destruction of the sebaceous glands. Next in order, concomitant with the vascular reaction, is the rather sudden appearance of a great number of abnormal mitoses in the epithelial cells. It seems that the majority of the radiation effects in the cells do not occur unless the cells have divided after irradiation. Using the micronuclei as a sign of radiation effects, it is found that regeneration of the epithelium is effected by the irradiated cells; migration of non-irradiated epithelial cells into the irradiated field to replace the cells that have succumbed does not take place during the acute reaction following 2,700 r.

The physical conditions and the experimental arrangement give a well-defined field of irradiation with rather sharp borders, as shown by photometry of films exposed in the same position as the skin flap.

The irradiated epithelial cells near the border, which have received the same dose of irradiation as the cells in the middle of the field, give rise to a hyperplasia during the acute reaction with 6 to 12 cell layers instead of 2 to 3 layers in normal skin. Most of the epithelial cells in the middle parts of the irradiated field are destroyed at the time when the marginal hyperplasia develops. The hyperplasia is not correlated to any vascular changes detectable with the methods applied.

Shielding of as small a part as 1 sq. mm in the middle of the irradiated field of the flap is also followed by hyperplasia of the irradiated epithelium about the shielded spot.

The experiments therefore suggest the existence of some factor or factors present in non-irradiated, perhaps epithelial, cells, and able to a great extent to modify the effects of radiation on the adjoining epithelial cells.

Autoreview.

La Phlébographie Pelvienne par Voies Veineuse, Osseuse et Utérine. Par P. Guilhem et R. Baux. 134 pp., 75 illustrations. Masson et Cie, Paris 1954. Frcs. 1,500: —.

In a study of the pelvic veins, the authors have carried out phlebographies, in some cases injecting the contrast medium into the vena dorsalis penis (clitoridis), and in others by direct intraspongeous injection into the symphysis pubis, the region of the trochanter, or the tuber ischi, while in others again the musculature of the uterus was directly punctured (suprapubically and transvaginally).

The work is based on a material of 500 examinations. The normal anatomy is analyzed thoroughly. The authors have demonstrated thrombosis in the region of the hypogastric vein, after operation as well as after child-birth, and at the same time have been able to demonstrate the completely free passage of the vena femoralis and iliaca externa. It was found possible to study the collateral circulation. They have been able to indicate the extent of infiltration and the presence of metastases by carrying out phlebographies in cases of tumours in the pelvic region.

Folke Knutsson.

Die Bronchographie. Von Ernst Stutz und Heinz Vieten. 250 S., 181 Abb. Georg Thieme Verlag, Stuttgart 1955. DM. 66: —.

Developments in the field of intrathoracic roentgen diagnostics run parallel with advances in thoracic surgery. Just as angiocardiography has been of great importance in the diagnosis of intra-thoracic cardio-vascular diseases, modern developments in bronchography have enabled considerable broadening and precision in the diagnosis of pulmonary disease.

The techniques of bronchography are extensively dealt with in 40 pages. The various contrast media are treated together with different forms of anaesthesia, following which the authors describe the technique they employ and recommend. Thereafter, bronchial anatomy is treated in some detail in one chapter and the normal and pathologic physiology of the bronchi as demonstrated by bronchography in another one. Finally, the importance of bronchography in different pulmonary diseases is discussed at some length. The book ends with a bibliography comprising no less than 1,654 items.

The authors, without reserve, recommend water soluble contrast media, but it is to be regretted that they do not seem to have used Dionosil extensively enough to be able to form an opinion on the advantages of this agent which, in the reviewer's opinion, is superior to all other water soluble contrast media.

A large number of pages are devoted to a discussion of different anaesthetics, as well as to general anaesthesia, in cases of bronchography. It is difficult for a radiologist to say whether the authors deal with these problems competently but it is of interest to note that they express a warning against introducing adrenalin in bronchial anaesthetics, since the toxicity is thereby greatly increased. They mainly use a 0.5 % bronchiocain solution with an admixture of the wetting medium Tween 80. The importance of premedical treatment with luminal is emphasized, as well as the necessity of the possible exhibition of oxygen, incubation, evipan, caffeine and spasmolytics, should the patient be subject to spasms. The authors also point out that bronchography should be preceded by a thorough roentgen examination of the lungs, so that the objective of the examination may be formulated, and, if necessary, selective bronchography performed. The authors use Metras catheters, or the like, for injecting the contrast medium. Only one lung at a time is examined. The usefulness of lateral views, preferably in the upright position, is stressed. The authors express the view that bronchography, since it is not devoid of risks, should not be carried out ambulatory.

In the extensive chapter on bronchial anatomy, the authors do not employ the international nomenclature of 1950, which is to be regretted.

The long chapter on morphologic changes that may be present in the bronchial system in cases of disease of the lungs and surrounding regions is excellent, not less because of the fact that it also contains short descriptions of the pathologic, clinical, and roentgenologic aspects of the various diseases.

As a final comment it may be said that the presentation is good, the subject matter well arranged, and the illustrations excellent particularly from the standpoint of reproduction quality. Although the book in some parts may appear a little heavy and long-winded, it should be valuable to all who are interested in this field of radiology.

Bengt Holmgren.

BOOKS RECEIVED

We acknowledge with thanks under this heading books received for review, which we trust will be regarded as a sufficient mark of appreciation of the courtesy of the sender. The reviews of selected items will appear as soon as opportunity affords.

Radioisotope Conference 1954. Vol. I. Medicine, agriculture and biological sciences. — Vol. II. Physical sciences and industrial applications. Butterworths Scientific Publications, London 1954.

La Aortografia Abdominale. Ramon Carrilo, Raul E. Matua, Juan de Dulacska. Lopez-Etchegoyen, Buenos Aires 1954.

Handbook of Radiology. Editor: Russell H. Morgan. The Year Book Publishers Inc., Chicago 1955.

Operative Cholangiographie. Von Walter Hess. Georg Thieme Verlag, Stuttgart 1955.

Röntgenologische Funktionsdiagnostik mittels Serienaufnahmen und Kinematographie. Von R. Janker. 2 Bände. Verlag W. Girardet, Wuppertal-Elberfeld 1954.

Selected Papers from the Institute of Cancer Research, Royal Cancer Hospital and from the Royal Cancer Hospital. Vol. 8. 1952—1953.

Advances in Pediatrics. Vol. VII. Editor: S. Z. Levine. The Year Book Publishers Inc., Chicago 1955.

Bronchus und Tuberkulose. Von A. Huzly und F. Böhm. Georg Thieme Verlag, Stuttgart 1955.

Fluoroscopy in Diagnostic Roentgenology. By Otto Deutschberger. W. B. Saunders Company, Philadelphia 1955.